PB84-194463

Analysis of Costs for Compliance with Federal Radiation Protection Guidance for Occupational Exposure. Volume 1: Cost of Compliance with Proposed Radiation Protection Guidance for Workers

Faucett (Jack) Associates, Inc., Chevy Chase, MD

Prepared for

Office of Radiation Programs, Washington, DC

Nov 83

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO 520/1-83-013-1	2.	3. RECIPIENT'S ACCESSION NO. PB84 194463
4. TITLE AND SUBTITLE Analysis of Costs for Compliance with Federal Radiation Protection Guidance for Occupational Exposure		5. REPORT DATE November 1983 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jack Faucett Associates S. Cohen and Associates, Inc.		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Same as box 12.		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency 401 M Street, S.W Washington. D.C. 20460		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

On January 23, 1981 the Office of Radiation Programs, U.S. Environmental Protection Agency published in the Federal Register proposals for revisions in the existing Federal Radition Protection Guidance for Occupational Exposures. This report is a part of the continuing analysis by EPA of the cost/feasibility of the proposed revisions. Specificall the report evaluates each of the proposed changes in the guidance to estimate the cost of compliance to all segments of the private sector wherein impacts are expected to be significant.

This study concentrates its effort on estimating the direct resource costs[1] for each industry that must comply with the regulations that result from the revision to the guidance. These costs that are met by industry participants will account for a significant portion of the total costs associated with the guidance. These costs were estimated through a series of case studies[2] and independent research.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT unlimited	19. SECURITY CLASS *(This Report)* unclassified	21. NO. OF PAGES 148
	20. SECURITY CLASS *(This page)* unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Office of
Radiation Programs
Washington DC 20460

EPA 520/1-83-013-1
November 1983

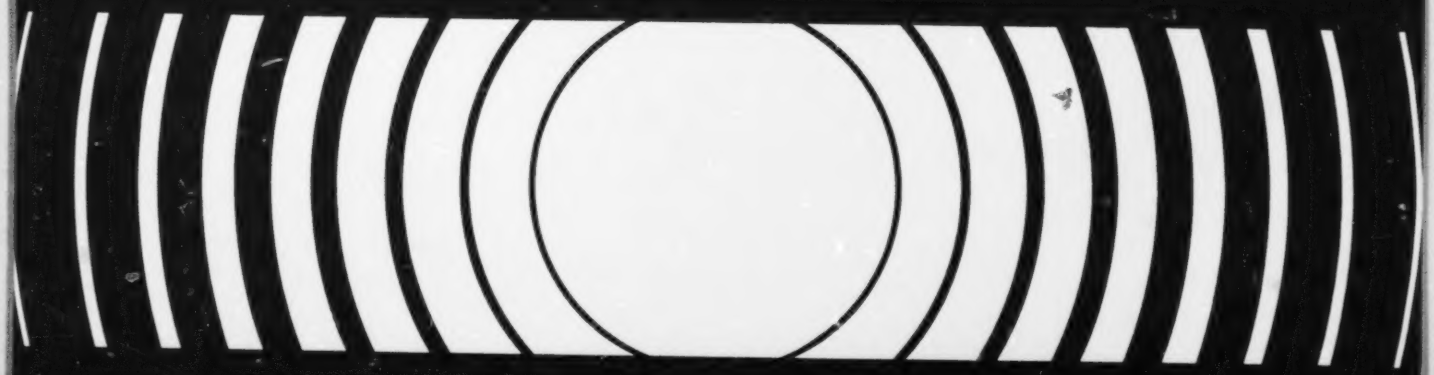
PB84-194463

Radiation

EPA

Analysis of Costs for Compliance with Federal Radiation Protection Guidance for Occupational Exposure

Volume I



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

DISCLAIMER NOTICE

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Environmental Protection Agency or the U.S. Government.

EPA 520/1-83-013-1

Analysis of Costs for Compliance with Federal Radiation Protection Guidance for Occupational Exposure

(Proposed on January 23, 1981)

Volume I: Cost of Compliance with Proposed Radiation Protection Guidance for Workers

November 1983

Prepared under Contract No. 68-01-6486
by Jack Faucett Associates
Chevy Chase, Maryland
and
S. Cohen and Associates, Inc.
McLean, Virginia

Office of Radiation Programs
Environmental Protection Agency
Washington, D.C. 20460

i.a

TABLE OF CONTENTS

CHAPTER PAGE

1 SUMMARY 1

2 INTRODUCTION 15

3 COST OF COMPLIANCE: HOSPITAL/CLINIC 22

3.1 Industry Profile: Hospitals 22
3.2 Cost of Compliance with Guidance 25
3.3 Summary of Cost of Compliance 38

4 COST OF COMPLIANCE: PRIVATE MEDICAL 40

4.1 Industry Profile: Private Medical 40
4.2 Cost of Compliance with Guidance 42
4.3 Summary of Cost of Compliance 46

5 COST OF COMPLIANCE: INDUSTRIAL RADIOGRAPHY 47

5.1 Industry Profile: Industrial Radiography 47
5.2 Cost of Compliance with Guidance 49
5.3 Summary of Cost of Compliance 54

6 COST OF COMPLIANCE: MANUFACTURE AND DISTRIBUTION OF LARGE SOURCES 56

6.1 Industry Profile: Large Sources 56
6.2 Cost of Compliance with Guidance 56
6.3 Summary of Cost of Compliance 62

7 COST OF COMPLIANCE: MANUFACTURE AND DISTRIBUTION OF SMALL SOURCES 63

7.1 Industry Profile: Small Sources 63
7.2 Cost of Compliance with Guidance 64
7.3 Summary of Cost of Compliance 69

8 COST OF COMPLIANCE: DENTAL PRACTICE 70

8.1 Industry Profile: Dental Practice 70
8.2 Cost of Compliance with Guidance 72

9 COST OF COMPLIANCE: WELL LOGGING 73

9.1 Industry Profile: Well Logging 73
9.2 Cost of Compliance with Guidance 74
9.3 Summary of Cost of Compliance 78

TABLE OF CONTENTS (Continued)

CHAPTER PAGE

10 COST OF COMPLIANCE: NUCLEAR FUEL PROCESSING AND FABRICATION 80

10.1 Industry Profile: Fuel Fabrication 80
10.2 Cost of Compliance with Guidance 81
10.3 Summary of Cost of Compliance 89

11 COST OF COMPLIANCE: COMMERCIAL POWER REACTORS . . . 90

11.1 Industry Profile: Commercial Power Reactors 90
11.2 Cost of Compliance with Guidance 93
11.3 Summary of Cost of Compliance 103

12 COST OF COMPLIANCE: UNIVERSITY REACTORS. 105

12.1 Industry Profile: University Reactors 105
12.2 Cost of Compliance with Guidance 105
12.3 Summary of cost of Compliance 108

13 COST OF COMPLIANCE: NUCLEAR PHARMACY 109

13.1 Industry Profile: Nuclear Pharmacies 109
13.2 Cost of Compliance with Guidance 109
13.3 Summary of Cost of Compliance 112

14 COST OF COMPLIANCE: URANIUM MILL. 113

14.1 Industry Profile: Uranium Mill 113
14.2 Cost of Compliance with Guidance 113
14.3 Summary of Cost of Compliance 118

15 COST OF COMPLIANCE: URANIUM CONVERSION PLANT 119

15.1 Industry Profile: Uranium Conversion. 119
15.2 Cost of Compliance with Guidance 119
15.3 Summary of Cost of Compliance 124

16 COST OF COMPLIANCE: OTHER INDUSTRIES. 125

16.1 Industry Profiles: Other Industries 125

APPENDIX A

Reprint of Federal Register - 5/18-60 128

Federal Register - 1/23/81 130

LIST OF TABLES

TABLE		PAGE
1	Estimated Cost of Compliance witn Proposed Radiation Protection Guidance for Workers	4
2	Summary of High Exposure Data for 1975	16
3	Summary of Proposed Changes in Occupational Radiation Protection Guidance	19
4	Radiation Therapy or Diagnostic Services Offered by Hospitals, 1980	23
5	Hospital Cost Estimating for Range C Compliance	30
6	Cost Estimate - Annual	31
7	Cost Estimate for Female Dual Badging	34
8	Cost of Internal Monitoring (Nuclear Medicine Departments)	35
9	Cost of Ideal Hospital Program	37
10	Cost Estimate Range B Requirements in Private Medicine	44
11	Cost Estimate for Training Requirements in Private Medicine	44
12	Cost Estimate for Internal Exposure Requirements in Private Medicine	45
13	Cost Estimate for Range C Requirements in Industrial Radiography	52
14	Cost Estimate for Range B Requirements in Industrial Radiography	52
15	Cost Estimate for Training Requirements in Industrial Radiography	53
16	Cost Estimate for Alternative Whole Body Limit for Industrial Radiography	54
17	Cost Estimate of Qualifying Installers as Health Physics Technicians	57
18	Cost Estimate of Additional Installation Teams	58
19	Cost Estimate of Qualifying Health Physicists In-House at Large Source Manufacture	59
20	Cost Estimate for Training Requirements in the Manufacture and Distribution of Large Sources	60

LIST OF TABLES (Continued)

TABLE		PAGE
21	Cost Estimate for Internal Exposure Requirements in the Manufacture and Distribution of Large Sources	61
22	Number and Type of Personnel Required in the Small Source Case Study Firm	66
23	Cost Estimate for the Small Source Case Study Firm.	67
24	Cost Estimate for Interval Exposure Requirements for Small Source Manufacture	68
25	Cost Estimate for the Alternate Whole Body Limit for Small Source Manufacture	68
26	Cost Estimate for Range C Requirements for Well Logging . .	76
27	Guidance Estimate for Training Requirements for Well Logging	77
28	Cost Estimate for Range C Requirements for Fuel Fabrication	82
29	Cost Estimate for Training Requirements for Fuel Fabrication	83
30	Initial Cost Estimate for Large LWR Fuel Case Study Firm . .	83
31	Estimate of Option 1 (modification of monitoring system) for Small LWR Fuel Case Study Firm	86
32	Cost Estimate of Option 2 (glove box containment) for Small LWR Fuel Case Study Firm	87
33	Summary of Cost for LWR Fuel Industry	86
34	Summary of Annual Information Reported by Commercial Light Water Cooled Reactors	91
35	Summary Distribution of Annual Whole Body Doses at Commercial Light Water Cooled Reactors.	92
36	Total Estimated Costs for all Operating Nuclear Power Plants of Reducing Regulatory Limits	95
37	Cost of Revised Internal Monitoring for a Large Mill (Nominal Capacity 3,000 Tons Ore/Day).	117
38	Cost of Revised Internal Monitoring for a UF_6 Conversion Facility	123

CHAPTER 1

SUMMARY

On January 23, 1981 the Office of Radiation Programs, U.S. Environmental Protection Agency published in the Federal Register proposals for revisions in the existing Federal Radiation Protection Guidance for Occupational Exposures.[1] This activity, undertaken by EPA under authority given the Agency in Executive Order 10831, the Reorganization plan of 1970 and Public Law 86-370, solicited comments from the radiation protection community, the impacted industries and individuals as to the advisability of the proposed changes from both a health physics and compliance cost/feasibility viewpoint. Subsequent to the publication of the proposed guidance, the agency chaired public hearings and accepted written comments from interested parties.

This report is a part of the continuing analysis by EPA of the cost/feasibility of the proposed revisions. Specifically, the report evaluates each of the proposed changes in the guidance to estimate the cost of compliance to all segments of the private sector wherein impacts are expected to be significant. The potential cost impacts of the following proposed changes in the guidance are evaluated:

1. Limit on the annual whole-body exposure

2. Limit on the allowable lifetime exposure

3. Reduction in allowable exposures to extremities, eyes and other organs

4. Special procedures for workplace control, worker training and monitoring when exposures are anticipated to be less than a radiation protection guideline, but greater than 30 percent of the guideline (RANGE C EXPOSURES)

5. Special procedures for workplace control, worker training and monitoring when exposures are anticipated to be between 10 and 30 percent of the radiation protection guidelines (RANGE B EXPOSURES)

---

[1] *The current guidance was published in 1960 (25 FR 4402). Copies of the 1960 Guidance and proposed revisions as published are reproduced in Appendix A of this report.*

6. Training of all potentially exposed workers in radiation protection principles and quantitative levels of risk

7. Alternatives for protection of the unborn
   a. women able to bare children voluntarily keep dose to unborn less than .5 rem during pregnancy
   b. in addition, women able to bear children voluntarily avoid jobs with exposure greater than .2 rem/mo.
   c. b. is made mandatory

8. Internal exposure monitoring and calculation

In addition, a ninth item, the reduction of the whole-body RPG to 1.5 rem, is also evaluated to test the sensitivity of cost to changes in the whole-body RPG.

This study concentrates its effort on estimating the direct resource costs[1] for each industry that must comply with the regulations that result from the revision to the guidance. These costs that are met by industry participants will account for a significant portion of the total costs associated with the guidance. These costs were estimated through a series of case studies[2] and independent research.

RESULTS

The compliance costs of the proposed EPA guidelines have been estimated for several industries including: hospitals, the private practice of medicine, industrial radiography, well logging, nuclear fuel fabrication, manufacture and distribution of radioactive sources, dental practices, research reactors, nuclear pharmacies, uranium mills, uranium conversion facilities, and commercial power reactors. Cost estimates have been drawn from data collected during case studies of representative establishments in conjunction with industry profiles.

---

[1] *For convenience, in the remainder of this report, direct resource costs will be referred to simply as costs.*

[2] *Case Study Analysis of the Impacts of Proposed Radiation Protection Guidance for Workers, Jack Faucett Asociates, prepared for EPA/ORP, July 12, 1983.*

It was frequently not possible to specify confidently how a case study firm and its industry would respond to a proposed guidance. In some cases, several interpretations of a guidance were feasible; in other cases, our knowledge of the industry was too limited to predict with certainty its response to the guidance. It was necessary, then, to estimate the impact of each of several options or scenarios under a proposed guidance such that cost bounds of specific parts of the guidance could be established. To refine these estimates and assess their probability, further analysis will be necessary.

The estimated cost impacts (see Table 1) appear to be primarily recurring annual costs associated with additional personnel. Range C compliance results in almost $600 million in compliance costs with the bulk of these costs occurring in hospitals and power reactors. The next highest recurring cost occur in compliance with Range B with hospitals accounting for $20 of $27 million. Significant annual costs of less than $10 million each are estimated for the lifetime limit, training and internal exposures. Initial costs in nuclear fuel fabrication for internal exposure compliance account for $20 of the $27 million in this category. Limited costs for compliance with Range C in hospitals account for the other major initial cost impact.

Compliance costs associated with the alternate whole-body limit of 1.5 rem per year are dominated by hospitals. The $400 million estimate for hospitals is based on a case study establishment that established an extremely aggressive program to reduce all exposures. This large establishment not only complied with the 1.5 rem limit, but also complied with all other sections of the guidance. Their costs were extrapolated to all other hospitals to estimate the industry compliance cost. However, it is conceivable that high doses in hospitals could be reduced with an addition of personnel or a combination of personnel and monitoring. Such a program would limit the cost of compliance. It is unclear whether enough qualified persons would be available to undertake such an expansion.

TABLE 1

ESTIMATED COST OF COMPLIANCE WITH PROPOSED RADIATION PROTECTION GUIDANCE FOR WORKERS

(Millions of 1982 Dollars)

INDUSTRY	-3-[a] Hospitals		-4- Private Medicine		-5- Industrial Radiography		-6- Large Sources		-7- Small Sources	
GUIDANCE	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
(1) 5 Rem Annual Limit	—	—	—	—	—	—	—	—	—	1
(2) Lifetime Limit	—	—	—	—	—	—	—	—	—	—
(3) Extremities & Organs	—	—	—	—	—	—	—	—	—	—
(4) Range C	6	354[b]	—	—	—	13	—	1	—	2
(5) Range B	—	21	—	4	—	2	—	—	—	—
(6) Training	—	2	—	2	—	1	—	—	—	—
(7) Unborn Protection	—	1	—	—	—	—	—	—	—	—
(8) Internal Exposure	2	—	1	—	—	—	—	—	—	—
TOTAL (1-8)	8	378	1	6	—	16	—	1	—	3
(9) Alternate Whole-body - 1.5 Rem Annual Limit	—	400[c]	—	—	—	23	—	4	—	3

[a] *Number refers to chapter number in report.*

[b] *An alternative analysis results in a lower cost of about $170 million in annual cost and $2 million in initial outlays. This analysis is based on an assumption about the number of hospitals effected. (see pp 26-30 for a comparison of the alternatives)*

[c] *A less expensive alternative of increases in staff of radiation workers (and therefore collective dose) could reduce this cost to about $130 million. However, the large numbers of newly trained professionals and technicians to expand the staff may not be available at any reasonable cost.*

NOTE:
- — *All dollars are 1982.*
- — *Where no cost estimate is shown cost is expected to be less than $500,000 for this industry and cost element.*

TABLE 1 (Continued)

ESTIMATED COST OF COMPLIANCE WITH PROPOSED RADIATION PROTECTION GUIDANCE FOR WORKERS

(Millions of 1982 Dollars)

INDUSTRY	-8- Dental Practice		-9- Well Logging		-10- Fuel Fabrication		-11- Power Reactors		-12- University Reactors	
GUIDANCE	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
(1) 5 Rem Annual Limit	—	—	—	—	—	—	—	—	—	—
(2) Lifetime Limit	—	—	—	—	—	—	—	8	—	—
(3) Extremities & Organs	—	—	—	—	—	—	—	—	—	—
(4) Range C	—	—	—	20	—	1	3	243	—	—
(5) Range B	—	—	—	—	—	—	—	—	—	—
(6) Training	—	—	—	—	—	—	—	—	—	—
(7) Unborn Protection	—	—	—	—	—	—	—	—	—	—
(8) Internal Exposure	—	—	—	—	2[d]	1	2	—	—	—
TOTAL (1-8)	—	—	—	20	2	2	5	251	—	—
(9) Alternate Whole-body - 1.5 Rem Annual Limit	—	—	—	20	20	4	3	200	—	—

[d] *There is substantial uncertainty as to the expected cost for the internal exposure requirements in fuel fabricating facilities. One estimate assumes substantial capital investments in older facilities resulting in $20 million in initial outlays. Alternative procedures proposed by newer facilities may be applicable to all facilities thus reducing initial cost to $1-2 million and annual cost to about $500,000. (see pp 83-88 for description of alternatives.)*

TABLE 1 (Continued)

ESTIMATED COST OF COMPLIANCE WITH PROPOSED RADIATION PROTECTION GUIDANCE FOR WORKERS

(Millions of 1982 Dollars)

INDUSTRY GUIDANCE	-13- Nuclear Pharmacy		-14- Uranium Mill		-15- Uranium Conversion		-16- Other Industries		Total	
	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual	Initial	Annual
(1) 5 Rem Annual Limit	—	—	—	—	—	—	—	—	—	1
(2) Lifetime Limit	—	—	—	—	—	—	—	—	—	8
(3) Extremities & Organs	—	—	—	—	—	—	—	—	—	—
(4) Range C	—	—	—	1	—	—	—	—	9	635
(5) Range B	—	—	—	—	—	—	—	—	—	27
(6) Training	—	—	—	—	—	—	—	2	—	7
(7) Unborn Protection	—	—	—	—	—	—	—	—	—	1
(8) Internal Exposure	—	—	2	3	—	1	—	2	9	5
TOTAL (1-8)	—	—	2	4	—	1	—	2	18	684
(9) Alternate Whole-body - 1.5 Rem Annual Limit	—	—	—	1	—	—	—	—	23	655

Hospitals

The 5.0 rem/year and accumulated lifetime exposure limits would have no impact on the industry. The guidance on exposure to extremities and organs would also have no impact.

The proposed guidances for Range C (1.5 - 5.0 rem/yr.) and Range B (0.5 - 1.5 rem/yr.) would result in compliance costs, and these depend on the interpretation of the guidance. Under a strict interpretation of the guidance on Range C, all hospitals with nuclear medicine would be required to respond. The annual costs to the industry would be $350 million after an initial outlay of less than $10 million. The annual costs for a liberal interpretation of the guidance, which encompasses only large hospitals (i.e. more than 200 beds), would be $ 170 million with initial outlays of $2 million. The continuing costs are primarily associated with additional health physics professional and technical staff.

The guidance on Range B affects all hospitals with diagnostic radiology departments, and therefore encompasses an estimated 7,000 hospitals in the industry. Since hospitals responding to the guidance on Range C also satisfy Range B, only the 3,300 hospitals without nuclear medicine departments would have to hire part-time consultants under the liberal interpretation presented above. The total annual costs are estimated to be about $10 million. Under a strict interpretation, small hospitals with nuclear medicine departments also would have to respond to Range B, and the total annual costs could reach $22 million. If Range C were not promulgated, total cost for Range B are estimated to be about $24 million.

The proposed training requirements are currently being satisfied, with the exception of instruction in quantitative levels of risk. It is estimated that to satisfy this additional intent, estimated costs are $1.5 million annually under the assumption that Range B and C are promulgated. If they are not, estimated instructor cost would be $5.1 million annually.

The industry currently operates under voluntary programs similar to or precisely the same as the unborn protection provided by Alternative a. Alternative b specifies that the women able to have children would voluntarily avoid jobs with exposure greater than .2 rem/mo. Few hospital workers would be affected by this alternative. The professionally rewarding nature of the potentially high exposure assignments (e.g., diagnostic radiography special procedures) would limit the workers requesting other assignments and thus only negligible costs to the industry are expected.

The costs of the mandatory provisions of Alternative c depend on the acceptability of under-the-apron badging. Such badging would eliminate assignments with recorded exposures in excess of .2 rem/mo. in radiography and cardiology. A second badge for each affected worker (assuming collar badge is still worn) would result in just less than $1 million cost. If such badging were not permitted for compliance, women would be barred from these activities and severe labor shortages would develop that could limit available services.

The proposed guidelines on internal exposure would require routine measurement of uptake of radioiodine during thyroid scans. The one-time costs for recalibrating the existing scanning devises; providing instruction in self-monitoring to an average of two technicians per hospital; and satisfying regulators that broad license holders would not require a program beyond that currently in use are expected to cost industry about $2 million.

Under the alternate 1.5 rem whole-body limit, two options are possible. One is a vigorous radiation protection program similar to that operated by one of the case study firms. Such an industry-wide program would satisfy all portions of the guidelines and could cost industry about $400 million. The other option would be a doubling of the current staff to decrease individual exposure to less than 1.5 rem/year. The availability of labor to meet such an expansion is a serious limitation to this option.

Private Medical

The levels of exposure in this industry are relatively low. Therefore, there would be compliance costs only for the proposed guidances on Range B, training, and internal exposure. The annual costs of hiring part-time consultants to monitor Range B exposures are estimated to be $4 million. To instruct workers on levels of risk would cost an additional $2 million annually. And to recalibrate thyroid scanning devices for measurement of internal exposure would involve an initial, one-time cost of $1 million. Therefore, the annual costs of compliance would be approximately $6 million, and the first year costs, would be $1 million.

Industrial Radiography

The impact on industrial radiography is limited to the guidances on Range C, Range B, training, and the alternative 1.5 rem/year whole-body limit.

It is estimated that 25% of the approximately 750 firms in the industry would have to hire full-time health physicists to comply with the Range C guidance. The remaining firms would be required to hire part-time consultants to satisfy the requirements of Range B. The annual costs of these requirements are estimated to be $15 million.

Training in radiation protection principles is currently provided. To additionally instruct workers on levels of risk would cost approximately $800,000 annually for the 20,000 workers potentially exposed to radiation.

The impact of the alternate 1.5 rem/year limit would depend on the response of the industry. If other firms in the industry take up the workload of active firms whose growth would be limited by the 1.5 rem/limit, then there would be no cost to the industry.[1] However, if the active firms hire additional workers to lower individual exposures, productivity in these firms would decrease. This would produce a larger, less productive workforce at an annual cost of approximately $23 million.

In summary, annual compliance costs in this industry could be $16 million if the 5.0 rem/year RPG were implemented. If the alternative 1.5 rem/year RPG was enforced, then the annual costs to the industry could total $23 million.

Manufacture and Distribution of Large Sources

The compliances costs of the case study firm have been generalized to the five firms in the industry. These costs relate to the requirements on Range C, instruction on levels of risk, internal exposure, and the alternative annual whole-body limit.

---

[1] *This would, however, be a substantial economic impact, rearranging market structure, corporate performance and affecting job security.*

Several options were considered for minimizing the cost of Range C compliance. It is believed that training current staff to qualify as health physics professionals who could monitor the high exposure activity would result in the lowest compliance cost of $150,000 in initial cost and $600,000 in annual costs.

Instruction on levels of risk for the industry's 400 potentially exposed workers would cost approximately $6,000 annually. An internal dosimetry program for the industry's 25 workers with potential internal exposure would cost approximately $17,000 per year. Finally, to reduce individual exposure to less than 1.5 rem/year would require an expansion of 125 in the number of workers in the industry and an annual cost of about $4 million.

Manufacture and Distribution of Small Sources

The principal costs of compliance involve an increase in personnel in response to the 5 and 1.5 rem limits on annual whole-body exposure, and to the guidance on Range C. In addition, a computerized accounting system would be necessary to monitor internal exposures.

The impact of the 5.0 rem/year RPG will depend on whether the industry decides to increase radiation protection activities, or lower individual exposure by expanding the portion of the workforce receiving exposures in excess of 5 rem/year (and consequently increasing collective dose). The impact of the first option has not been estimated since it is subsumed in the response to the guidance on Range C. The total costs of the second option, expansion of the affected workforce by 50%, is estimated to be about $550,000.

The guidance on Range C would require supervisory personnel in four activities where annual exposures are anticipated in excess of 1.5 rem/year, and an expansion in the number of drivers and trucks to reduce individual exposure in transport of sources to less than 1.5 rem/year. The compliance costs of these requirements would depend on the interpretation of the guidance. A strict interpretation would require that all supervisory personnel be radiation protection professionals, whereas a liberal interpretation would allow delegation of supervisory responsibilities to radiologic technicians for activities where exposures are accumulated uniformly. The respective annual costs of the two interpretations are about $2 million with about $250,000 higher cost for the strict interpretation. There would also be initial costs of $300,000 for 10 additional trucks under both interpretations.

The third impact of the guidelines relates to internal exposure. The mechanics of compliance would require a computerized accounting system. The initial, one-time costs to the industry for programming are estimated to be $34,000.

The final impact relates to the alternative 1.5 rem/yr. whole-body limit. Two alternatives exist to satisfy this requirement: replace existing hardware or an expansion in the workforce. A cost estimate of the first option is not available. The second option would cost the industry $3 million per year.

Well Logging

Compliance costs would result from the satisfying guidelines on Range C, Range B, and the alternative 1.5 rem/year limit. Three options were considered for compliance with the requirements of Range C, but only the costs of the medium and least-cost options were estimated. The medium-cost option would have full-time health physicists at each firm (but not at each field site) at an estimated annual cost of $20 million. The least-cost option substitutes consultants for full-time personnel to fulfill the supervisory role. The costs of this option are estimated to be $5 million. Staff time for training on the risks of exposure could add about $150,000 to total the annual cost.

All firms would be required to respond to Range B, but the costs of satisfying this requirement are subsumed under Range C. All major firms currently comply with Range B. If Range C were not promulgated, these firms would incur few costs, but the 300 other firms in the industry could incur $300,000 in annual cost. As for the alternative 1.5 rem/year whole-body limit, the industry is currently on the borderline of meeting this requirement. Assuming that the combined impact of additional health physics personnel and instruction of field engineers would result in compliance, then the cost of the 1.5 rem/year limits would be equal to the compliance costs of the industry's response to the Range C guidance.

Fuel Fabrication

Cost impacts for this industry are concentrated in Range C requirements for staff training and in monitoring of internal exposures. It is estimated that the industry would incur annual costs of $680,000 for Range C if non-professional health physics personnel are not permitted to assume supervisory responsibilities.

With the exception of instruction in levels of risk, the training requirements in the proposed guidelines are currently being satisfied. To additionally provide instruction in levels of risk to the industry's 4,000 potentially exposed workers would cost approximately $130,000 annually.

The control of internal exposures is the highest potential cost area for this industry, yet it is also the one for which the least is understood by either industry or the regulators. If the five firms that make up this industry respond by modifying the calculational procedures on airborne concentration, particle size, enrichment, solubility, and worker time-in-area, then the result in annual industry costs could be three or four hundred thousand dollars and initial costs of $1 to $2 million. However, if the two small firms opt for glove box containment as suggested by a case study, then the annual costs rise to $3 million, and initial costs could be $20.6 million. This alternative is believed to be less likely because it could put the smaller firms out of business.

Compliance with the alternative 1.5 rem/year limit would not be a problem for this industry with respect to external exposures. However, the summation of internal and external exposures could present compliance difficulties. This risk could be eliminated by a program similar to the internal exposure estimates described above.

Commercial Power Reactors

Cost of compliance with the proposed guidelines are significant for this industry. Major cost impacts occur in the whole-body limit, lifetime limit, Range C and internal exposures guidances.

The 5.0 rem/year limit could result in the need for about 300 additional outside workers at an annual cost of $350,000. For the alternative 1.5 rem/year limit, about 1,300 permanent station workers and 24,000 outside workers would be required. In addition, there would be costs relating to outage extension and additional facilities. The combined annual costs of additional operating expenses and personnel are estimated to be $200 million. Initial expenses for additional facilities are estimated to be $3 million.

Other costs would include $7.5 million for addition of several specially skilled workers for work in high radiation fields. Additional workers would reduce the likelihood of any workers exceeding the lifetime limits. Compliance with Range C would require a substantial staff increase in health physics technicians. It is estimated that the current staff of HP technicians at the 54 operating sites would have to be doubled to provide monitoring required by Range C. The cost to the utilities of these staff is estimated to be about $250 million. On the other hand, these costs would be greater than the cost for operating within the 1.5 rem/year limit, that is $200 million annually and $3 million initial expenditures. An additional $2 million in one-time programming and software modifications for internal monitoring would be expected. Thus it is expected that utilities would choose to operate below the 1.5 rem/year limit, thus eliminating Range C monitoring requirements.

Nuclear Pharmacies

This industry which has developed over the past decade is dominated by two firms. The cost of compliance is estimated to be entirely concentrated in activities associated with the upgrading of software to account for the changes in the internal exposure guidance. Costs are expected to be about $20,000 per year.

Uranium Mill

Impacts of the guidelines on the 20 currently operating uranium mills are expected to be concentrated in Range C compliance and in internal exposure control, monitoring, and recordkeeping. The addition of health physicists to the mill staff for compliance with Range C is estimated to cost $1 million annually. The determination and monitoring of particle size and solubility of materials and the development of a recordkeeping system for these data are expected to cost the industry $1.5 million to establish and $3 million annually to maintain. The alternate whole-body limit of 1.5 rem would result in costs equal to the Range C compliance costs.

Uranium Conversion

Only two uranium conversion facilities currently operate in the U.S. Impacts from the Range C requirements are estimated to cost the industry $100,000 per year for the expansion of the health physics staff. The development of a particle size and solubility monitoring and recording system to comply with the internal exposure guidance is expected to cost the industry $250,000 initially and $500,000 annually.

Other Industries

Compliance costs for other industries where case studies were not conducted have been estimated utilizing secondary data. These industries include education, operators of irradiators, podiatry, chiropractic medicine, veterinary medicine, and users of industrial guages. The impacts on transportation of radioisotopes were not estimated because sufficient information was not available.

Except for veterinary medicine, exposures should be in Range A if equipment is operated properly and procedures are followed. Under these conditions, the only portion of the proposed guidelines that could impose a cost is that of training, assuming that workers are not instructed in levels of risk. To quantify this cost for each industry, we used the per worker training cost from a comparable industry treated in the case studies. For example, the per worker cost for training personnel in podiatry, chiropractic medicine, and veterinary medicine was assumed to be approximately equal to that of other private medical practices, i.e., $20. Using this approach, the combined annual costs for training amounted to approximately $2 million.

The other compliance costs relate to Range B exposures in veterinary medicine. Here the Range B cost per worker in private medical practice was used, and the annual costs totaled $300,000 for the approximately 10,400 veterinary offices in operation were estimated.

CHAPTER 2

INTRODUCTION

The Office of Radiation Programs, (ORP) has been reviewing the 1960 radiation protection guidance for workers since 1974. The Office has sponsored a major study by the National Academy of Sciences - National Research Council Committee on the Biological Effects of Ionizing Radiation (BEIR) and conducted a study of the 1975 radiation workforce.[1] Utilizing these studies, consultation with other affected Federal agencies and other data, ORP issued a proposed set of revised guidelines for public comment in the Federal Register on January 23, 1981. These guidelines were designed to address the allowable annual and lifetime radiation dose for workers, levels of supervision and training for categories of workers, internal and external exposures, exposure to specific organs, protection of the unborn, and other issues.[2]

Subsequent to the Federal Register notice, public hearings were held and written comments on all aspects of the proposal were received by ORP. Comments from interested parties made it clear that there was a substantial uncertainty as to the costs that would be borne by industry if the proposals were adapted. This uncertainty stems in part from the number and wide diversity of the economic sectors that employ radiation workers. The ORP study stated that in 1975 there were over one million radiation workers of which about forty percent were exposed to ionizing radiation. Table 2 provides a breakdown of these employment and exposure data by industry segment.

The estimates of the number of radiation workers by industry in 1975 were based on a sample of monitoring data provided by a large badging service firm. In general, the data provides a reasonable order of magnitude estimate of the size of the workforce. However, the failure to eliminate all room or area badges and badges with erroneous counts could seriously bias the data, particularly when the sample is expanded to cover the universe of radiation workers on a disaggregate industry and level of exposure basis.

---

[1] *Occupational Exposure to Ionizing Radiation in the United States: A Comprehensive Summary for the Year 1975, U.S. Environmental Protection Agency, Office of Radiation Programs, EPA, November 1980, EPA 520/4-80-001.*

[2] *The complete text is included in Appendix A.*

Table 2

SUMMARY OF HIGH EXPOSURE DATA FOR 1975

Activity	Estimated Total Number of Workers	Percent of Workers Exposed			Percent of Females Ages 18-39 Exposed to 0.5 rem
		5 rem	1.0-5.0 rem	0.5-1.0 rem	
1. Power Reactors	55,000	0.5%	12.8%	5.7%	16%
2. Industrial Radiography	20,000	0.4%	8.5%	6.4%	0%
3. Manufacturing & Distribution	11,000	0.5%	5.7%	4.2%	1%
4. Fuel Processing & Fabrication	11,000	0.7%	5.6%	5.9%	0%
5. Medical Hospital/ Clinic	100,000	0.2%	4.2%	5.6%	7%
6. Other Industrial	170,000	0.2%	3.5%	1.8%	1%
7. Veterinary	18,000	0.2%	1.1%	1.6%	3%
8. Medical Private	138,000	0.3%	2.5%	2.8%	4%
9. Waste Disposal	300	0.0%	0.0%	0.0%	No Data
10. Education	22,000	0.1%	1.5%	1.8%	2%
11. Dental	270,000	0.1%	0.5%	0.6%	1%
12. Podiatrists	10,000	0.0%	0.0%	0.0%	0%
13. Uranium Mills	300	0.0%	0.0%	0.0%	0%
14. Chiropractors	15,000	0.0%	0.2%	0.9%	No Data
15. Transportation	77,000	0.0%	0.2%	0.6%	No Data

Source: Occupational Exposure to Ionizing Radiation in the United States: A Comprehensive Summary for the Year 1975, U.S. Environmental Protection Agency, Office of Radiation Programs, EPA, November 1980, EPA 520/4-80-001.

The purpose of this study was to estimate the cost of compliance with each individual portion of the guidance. Further, these costs were to be estimated for each industry where significant impacts were expected. The diversity of the impacted industries eliminated the option of applying a common cost estimation methodology across all industries. Indeed, each industry appeared to have unique requirements for workers that led to industry specific radiation protection procedures and options. Each industry where significant cost impacts were anticipated required specific analysis of the job requirements, exposure history, and potential exposure for radiation workers. The available options for compliance with the guidelines were evaluated for technical and economic feasibility for each industry. In order to collect the required data a series of case studies were arranged. In each case a senior radiation protection professional and a senior economist spent one to two days at establishments in selected industries evaluating their radiation protection programs and options under the proposed guidance.

Representative case studies were selected[1] on the basis of potential impact, drawing heavily from the 1975 EPA study of occupational exposures.[2] Impact was defined as the degree to which a particular industry might be affected by the proposed guidelines. Numbers of workers potentially exposed in excess of 5 rem was not considered to be a sufficient criterion, since the establishment of a 5 rem/year whole-body RPG is only one part of the proposed guidance. (Also, many of the alleged annual exposures in excess of 5 rem in the 1975 data base may be anomalous as noted above.)

The following were considered as indicators of impact:

1. Numbers of whole-body exposures in excess of 5 rem
2. Numbers of whole-body exposures in Range B (0.5-1.5 rem) and Range C (1.5-5 rem)
3. Numbers of females of child-bearing age with exposures in excess 0.5 rem
4. Numbers of organ exposures in excess of the proposed RPG's
5. Numbers of workers with measurable internal exposures

---

[1] *For a detailed description of the case study selection procedure and results see: Case Study Analysis of the Impact of Proposed Radiation Protection Guidance for Workers, Jack Faucett Associates, prepared for EPA/ORP, July 12, 1983.*

[2] *Op. cit., EPA, EPA 520/4-80-001, November 1980.*

Cross-industry data were unavailable for items 4 and 5. Thus items 1 through 3 were used as the indicators of impact.[1] Final selection of case study industries were made using these data, specific needs of ORP, requests from the Nuclear Regulatory Commission, and NRC data on exposure at licensed facilities.

A review of the public comments on the proposed guidance indicated that there was a substantial amount of confusion among the public as to the intent of several portions of the guidelines. Prior to conducting any case studies it was necessary to develop a clear definition of the intent for each section of the guidance so that fruitful discussion of cost, exposure and available protection options could be undertaken with each case study firm. Working with the ORP personnel responsible for the proposed guidelines the case study staff developed a list (presented in Table 3) which segregated the proposed guidance into several separate issues. These issues formed the basis for the conduct of each case study. The list, which was provided to each prospective case study firm, compared language and data from the 1960 guidance with the proposed new guidance. For each item interpretive assumptions were also developed and provided.

The information collected in the case studies was reviewed with other knowledgable individuals in each industry to develop the cost estimates provided here. These costs are the direct expenses that firms in each industry can be expected to face in order to satisfy the requirements of the guidance. No attempt has been made to estimate the benefits that stem from the guidance or indirect cost effects such as reduced product demand, changes in supply patterns, and the cost to individuals. Also not included are costs that may be associated with specific requirements placed on firms by regulations such as record keeping and reporting. These costs could be significant. In a related study for the Nuclear Regulatory Commission,[2] utilizing the same case study data incorporated here, evaluation of the proposed revisions to 10 CFR Part 20 for

---

[1] *The estimates of female exposures were taken from a contractor report, Occupational Exposures to Ionizing Radiation within the United States for the Year 1975-A Statistical Data Base, prepared by Teknekron, Inc., under EPA Contract No. 68-01-1953, July 1978.*

[2] *Jack Faucett Associates and S. Cohen and Associates, Inc., Cost of Compliance With Occupational Exposure Revisions to 10 CFR Part 20, prepared for the Nuclear Regulatory Commission, December 20, 1982.*

Table 3

SUMMARY OF PROPOSED CHANGES IN OCCUPATIONAL RADIATION PROTECTION GUIDANCE

REQUIREMENT	FRC GUIDANCE	PROPOSED NEW GUIDANCE	INTERPRETIVE ASSUMPTIONS
Justification	"...no man-made radiation exposure without the expectation of benefit..."	"...occupational exposure should be justified by the net benefit ... include considerations of alternatives not requiring exposure."	No substantive change from current requirements; i.e., no new paperwork required.
ALARA	"...encourage maintenance of radiation doses as far below this guide as practicable."	"...assure that collective dose is ALARA." Also, maintain individual doses and lifetime doses ALARA.	No substantive change from current requirements; i.e., no new paperwork required.
RPG's			
W.B.			
Rate	$\angle 3$ rem/qtr.	<5 rem/yr.[1]	The quarterly limit is eliminated.
Accumulated	$\angle 5(N-18)$ limit, where N = age.	<100 rem objective in lifetime.	Assume existing workers are grandfathered.
Internal Exposures	Individual critical organ limits carried out through MPC's (Radioactivity Concentration Guides)	$\Sigma w_i H_i < 5$ rem/yr., where H_i is annual dose equivalent and committed dose equiv.[2] to organ i, and: $w_{breast} = .2$ $w_{lung} = 0.16$ $w_{red\ bone\ marrow} = 0.16$ $w_{thyroid} = 0.04$ $w_{bone\ surfaces} = 0.03$ $w_{skin} = 0.01$ $w_{other\ organs} = 0.08$	Note constraints from subsequent requirements on gonads and other organs.
		Radioactivity Intake Factors (RIF's) calculated from the above.[3]	EPA will supply values of RIF's and corresponding MPC's, as in the Attachment.
Combined uniform W.B. and internal exposures.	Independent limits	W.B. + $\Sigma w_i H_i < 5$ rem/yr.	
Extremities and Individual Organs	Hands & forearms, feet & ankles < 25 rem/qtr. and $\angle 75$ rem/yr.	Hands $\angle 50$ rem/yr.	
	Head and trunk, active blood forming organs, gonads, or eye lens $\angle 3$ rem/qtr.	Eye lens or gonads < 5 rem/yr.	Includes external exposure and committed dose equivalent[2] from internal.
	Skin of W.B. & thyroid < 10 rem/qtr. and $\angle 30$ rem/yr.	Other organs < 30 rem/yr.	
	Bone $< 0.1\ \mu$gm Ra-226 or equiv. body burden		
	Other organs < 5 rem/qtr. and 15 rem/yr.		

---

[1] As an alternative, consider W.B. RPG < 1.5 rem/yr.

[2] "Annual committed dose equivalent" means the sum of all dose equivalents that may accumulate over an individual's remaining lifetime (usually taken as 50 years) from radioactivity that is taken into the body in a given year.

[3] If any specific RIF is larger than currently in use, use current limit.

Table 3 (Continued)

SUMMARY OF PROPOSED CHANGES IN OCCUPATIONAL RADIATION PROTECTION GUIDANCE
(Continued)

REQUIREMENT	FRC GUIDANCE	PROPOSED NEW GUIDANCE	INTERPRETIVE ASSUMPTIONS
Exposure of Minors	1/10 RPG's	1/10 RPG's	
Exposure of Unborn	No Guidance	Alternatives: i. Women voluntarily keep dose to unborn < 0.5 rem during known/suspected pregnancy. ii. Women able to bear children voluntarily avoid jobs with dose > 0.2 rem/mo., and keep dose to unborn < 0.5 rem during known pregnancy. iii. Women able to bear children limited to jobs with dose < 0.2 rem/mo. and dose to unborn < 0.5 rem.	Requirement on the unborn is assumed to be met if satisfied by the woman.
Lower Limits	Permitted after consideration by agency.	Agencies may set limits below RPG's and RIF's when appropriate.	Assume RPG's in this guidance for purposes of cost estimate. If any future lower limits, the other regulatory agencies would justify them separately.
Higher Limits	Permitted after consideration by agency.	Permitted after consideration by agency (but must be publicly disclosed).	Assume RPG's in this guidance for purposes of cost estimate. If any future lower limits, the other regulatory agencies would justify them separately.
Training	No guidance	All radiation workers must be instructed on levels of risk from radiation and radiation protection principles.	Quantitative guidance on risk.
Monitoring	No guidance	Range A (assume < 0.1 RPG): Monitor area exposure rates to assure exposures in range and ALARA.	Done once and for all unless changes in source and/or exposure configuration.
		Range B (assume ≥ 0.1 RPG and < 0.3 RPG): Monitor and record individual exposures.	Individual dosimeters and records.
		Range C (assume > 0.3 RPG and < 1.0 RPG): Monitor area exposure rates before and during tasks in addition to monitoring individual exposures.	Individual dosimeters and records plus surveys before and during tasks.
Supervision	No guidance	Range A (assume < 0.1 RPG): No requirements.	
		Range B (assume > 0.1 RPG and ≤ 0.3 RPG): Provide professional radiation protection supervision[4] sufficient to assure exposures justified and ALARA.	Assume radiation protection professional is available but not necessarily full-time. Also, assume no formal paperwork required.
		Range C (assume > 0.3 RPG and < 1.0 RPG): Provide professional radiation protection supervision[4] before and while tasks are undertaken which make significant contribution to exposures in this range and to assure exposures are ALARA.	Assume full-time radiation protection supervision. Exposure to the supervisor is not implied.

---

[4] Assume that a "radiation protection professional" is a certified Health Physicist, Medical Physicist, or individual with equivalent training and experience.

occupational exposure regulations concluded that compliance with NRC regulations and NRC Agreement State Regulations could cost $4 million for record keeping, $8 million for revisions to existing manuals and procedures, and $4 million for retraining of personnel. These costs are not attributable directly to the guidance as they are associated with specific regulatory actions.

CHAPTER 3

COST OF COMPLIANCE: HOSPITAL/CLINIC

3.1 INDUSTRY PROFILE: HOSPITALS

In 1980, American Hospital Association (AHA) survey results show a total of 6,965 registered hospitals located in 50 states and D.C.[1] providing a total of 1,365,000 beds[2]. The number of hospitals is down from a total of 7,015 and 6,988 registered hospitals in 1978 and 1979, respectively. Community hospitals[3] account for 5,830 of all registered hospitals in 1980 and for 988,387 of all patient beds. Just under 800 community hospitals are affiliated with medical schools.

Ten percent of all community hospitals contain 400 or more beds. Community hospitals with 100 to 400 beds now account for 43 percent of all hospitals and 51 percent of all patient beds. Small community hospitals (less than 100 beds) have declined in number since 1970 and in 1980 accounted for only about 15 percent of all beds.

Performance and Services

All registered hospitals in the U.S. admitted 38,892,000 patients in 1980 and recorded 262,951,000 outpatient visits. The vast majority of outpatients and admitted patients were serviced by community hospitals. Occupancy for all registered hospitals averaged 77.7 percent of all available beds in 1980 and 75.4 percent of all available community hospital beds. Over 19,500,000 surgical operations were performed in 1980 by those hospitals surveyed. Expenses at 4,377 community hospitals reporting to the AHA totaled $72.60 billion in 1980 or $1,893 per admission or $250 per inpatient day.

Table 4 highlights the number of hospitals responding to the AHA survey providing radiation therapy or diagnostic services in 1980. Radiation therapy is available at

---

[1] *An additional 71 registered hospitals are located in U.S.-dependent areas.*

[2] *Hospital Statistics, 1981 Edition, American Hospital Association.*

[3] *Community hospitals are classified by the AHA as non-federal, non-institutional, short-term (average length of stay less than 30 days), general and other special hospitals.*

Table 4:

RADIATION THERAPY OR DIAGNOSTIC SERVICES OFFERED BY HOSPITALS, 1980

CLASSIFICATION	TOTAL REPORTING	RADIATION THERAPY X-Ray No.	RADIATION THERAPY X-Ray %*	RADIATION THERAPY Megavoltage No.	RADIATION THERAPY Megavoltage %*	RADIOACTIVE IMPLANTS No.	RADIOACTIVE IMPLANTS %*	NUCLEAR MEDICINE Diagnostic No.	NUCLEAR MEDICINE Diagnostic %*	NUCLEAR MEDICINE Therapeutic No.	NUCLEAR MEDICINE Therapeutic %*	CT SCANNERS No.	CT SCANNERS %*	CARDIAC CATHETERIZATION No.	CARDIAC CATHETERIZATION %*
ALL HOSPITALS	6,277	1,154	18.4	910	14.5	1,414	22.5	3,689	58.8	1,485	23.7	1,242	19.8	954	15.2
6- 24 beds	234	5	2.1	2	0.9	0	0.0	24	10.3	1	0.4	5	2.1	1	0.4
25- 49 beds	995	15	1.5	2	0.2	13	1.3	215	21.6	11	1.1	17	1.7	4	0.4
50- 99 beds	1,502	52	3.5	17	1.1	67	4.5	650	43.3	53	3.5	38	2.56	17	1.1
100-199 beds	1,458	180	12.3	104	7.1	254	17.4	1,038	71.2	280	19.2	155	10.6	84	5.8
200-299 beds	772	224	29.0	169	21.9	309	40.0	683	88.5	320	41.5	250	32.4	182	23.6
300-399 beds	469	219	46.7	181	38.6	263	56.1	419	89.3	279	59.5	261	55.7	181	38.6
400-499 beds	319	167	52.4	155	48.6	205	64.3	284	89.0	224	70.2	210	65.8	177	55.5
500 or more	528	292	55.3	280	53.0	303	57.4	376	71.2	317	60.0	306	58.0	308	58.3
FEDERAL HOSPITALS	340	51	15.0	45	13.2	58	17.1	185	54.4	91	26.8	42	12.4	86	25.3
psychiatric	24	0	0.0	0	0.0	0	0.0	12	50.0	2	8.3	0	0.0	0	0.0
general & other	316	51	16.1	45	14.2	58	18.4	173	54.7	89	28.2	42	13.3	86	27.2
NON-FEDERAL HOSPITALS	5,937	1,103	18.6	865	14.6	1,356	22.8	3,504	59.0	1,394	23.5	1,200	20.2	868	14.6
psychiatric	454	7	1.5	1	0.2	2	0.4	20	4.4	2	0.4	4	0.9	0	0.0
TB & other respiratory	10	0	0.0	0	0.0	0	0.0	4	40.0	0	0.0	0	0.0	0	0.0
long-term general	137	6	4.4	2	1.5	2	1.5	15	10.9	2	1.5	0	0.0	0	0.0
short-term general	5,336	1,090	20.4	862	16.2	1,352	25.3	3,465	64.9	1,390	26.0	1,196	22.4	868	16.3
COMMUNITY HOSPITALS	5,393	1,090	20.8	862	16.3	1,352	25.5	3,465	65.5	1,390	26.3	1,195	22.6	867	16.4

*: percent of total number of hospitals reporting in particular class

SOURCE: American Hospital Association, Hospital Statistics, 1981, p. 191-197, Table 12A.

15 - 20 percent of all hospitals in the U.S., primarily at the larger hospitals with over 200 beds. Diagnostic radioisotope facilities are available at over 55 percent of all hospitals, and over 65 percent of all community hospitals. Special radiation services such as CT scanners and cardiac catheterization were available at 20 and 15 percent of all hospitals, again primarily at the larger-sized hospitals. Approximately 1,800[1] hospitals are licensed by the NRC for radiation services and an additional 1,800 facilities are licensed by agreement states.

There are approximately 3,700 hospitals that have nuclear medicine departments. Of these, 1,700 are large (200 or more beds) and 2,000 are small (less than 200 beds). Hospitals with radiation workers include those with Nuclear Medicine Departments, Radiation Therapy Departments, CT Scanning facilities, Cardiac Catheterization and Diagnostic Radiography Departments. The largest subcategory are those with Nuclear Medicine Departments and due to a lack of more detailed information, it is assumed for the performance of this study that any hospital with one or more of these facilities has a Nuclear Medicine Department.

Employment

Slightly less than 3,500,000 full-time equivalent (FTE) personnel worked in registered U.S. hospitals in 1980 compared to just less than 3,390,000 in 1979. Of this total, 2,873,000 FTE personnel were employed by community hospitals, most at hospitals with more than 100 beds. Community hospital employees were paid a total of $43,283,000 in 1980 in wages and benefits with an average salary of $13,010 per employee per year[2]. Approximately 70,000 employees are monitored at NRC licensed hospitals.

Physicians and dentists number only 57,292 out of all FTE personnel in all registered hospitals. Registered nurses and LPN's number 693,385 and 258,413, respectively. Statistics from the American College of Radiology show that 660 hospitals in the U.S. employ medical physicists full-time and an additional 520 hospitals employ medical physicists part-time. In addition, many large hospitals employ full-time health physicists such that about 1,000 hospitals have one or more health and/or medical physicists on staff. At least 50 percent of all pathologists in the U.S. are salaried and work exclusively for hospitals, administering about 25 percent of all nuclear medicine practiced. Total radiation workers employed in U.S. registered hospitals are estimated to number 100,000.

---

[1] *Op. Cit., NRC, NUREG-0714.*

[2] *Op. Cit., Hospital Statistics, 1981.*

3.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 — Annual Whole-Body Limit - 5 rem/year

Although the 1975 EPA Data Base[1] indicates 200 exposures in excess of 5 rem, it is believed that all hospitals currently comply with the proposed annual whole-body limit. Two reasons for this are improved health physics practice and more sophisticated technology. Therefore compliance would entail no costs.

Guidance #2 — Accumulated Lifetime Exposure - 100 rem

Except for hospitals with very active cardiac catheterization laboratories, there will be no impact for most hospitals. Very few cardiologists (of 2,000 performing catheterizations) would be expected to approach the 100 rem limit, which would shorten their careers under the proposed guidance. No cardiologists at the case study hospitals were known to be close to this limit, but if care were not taken, the case study staffs could foresee some doctors being affected by this provision. However, no data that were provided by the case study institutions supported this fear. It is felt that there would be no cost to the industry. The cost would be borne by the individual since so few cardiologists would be affected.

Guidance #3 - Exposure to Extremities and Organs

There exists considerable controversy relating to the hand exposures of radiologists during fluoroscopy. Exposure rates in the direct beam are very high, and although it is generally acknowledged that the direct beam is avoided, it is suspected that this prohibition is not universally regarded. Moreover, hand protection (lead-impregnated gloves) is seldom worn and monitoring (ring badges) is rarely performed. Therefore, quantitative data are virtually non-existent.

---

[1] *Op. Cit., EPA, 1975.*

Hand exposures for physicians performing cardiac catheterization have been evaluated in detail by Rueter.[1] In his judgment, exposures for this procedure are typically 5 to 10 mrem per catheterization performed. Therefore, for a physician performing the recommended (by the Inter-Society Commission for Heart Disease Resources) number of cardiac catheterizations (6 per week), hand exposures might be expected to be as high as 3 rem, well within proposed limits.

Most hospitals measure eye exposure with collar badges, and this is an acceptable health physics practice. Since these measurements are within the proposed annual 5 rem limit for eye exposure, the requirements relating to eye exposure would have no impact on the industry.

Guidance #4 - Anticipated Exposures in Range C (1.5 - 5.0 rem/yr.)

Hospitals which anticipate annual exposures to personnel above 1.5 rem could respond according to several interpretations of the proposed guidance, which range from strict to liberal:

1. A health physicist or medical physicist (radiation protection professional) must supervise all activities where significant exposures are anticipated. These activities include cardiac catheterization, diagnostic radiology (in special procedures), and nuclear medicine. Therefore, a minimum of three health physicists would be required in hospitals providing all of these services, and in hospitals with multiple special procedures rooms, more than three radiation protection professionals are required.

2. A radiologic technician is delegated supervisory responsibility for Range C activities, and a health physicist or medical physicist supervises the team of technicians.

3. A radiologist or nuclear physician with training and experience in health physics supervises Range C activities.

---

[1] *Fred Reuter, Bureau of Radiological Health, private communication, January 25, 1982.*

Options 1 and 3 did not appear feasible. Therefore, their costs were not estimated. Option 3 was excluded because a radiologist or nuclear physician, although experienced in health physics, is not considered equivalent to a health physicist or medical physicist according to the opinion of the President of the American Association of Physicists in Medicine.

Option 1 is not feasible because the current population of radiation protection professionals is not sufficiently large. A reasonable estimate of 7,300 health physicists would be demanded, assuming an average of three at each of the 1,800 large hospitals (with more than 200 beds) with Nuclear Medicine Departments, and one at each of the 1,900 smaller hospitals (less than 200 beds)with Nuclear Medicine Departments. This coverage would require approximately 70% of the total number of medical and health physicists currently in practice.

Currently about 1,000 hospitals have either health or medical physicists on staff. Of these, about 600 are part of an active health physics monitoring program and the balance are exclusively performing other functions such as therapy dose targeting and calculation. Option 2 would require those hospitals with Nuclear Medicine and no radiation protection professoinal on staff (about 2,700 hospitals) to hire staff with those qualifications. This option is also very difficult to imagine, but given enough lead time, the growing number of universities offering degrees in health or medical physics and related disciplines could meet the increased need.

In addition, option 2 appears to agree with the intent of the guidance, namely, supervision of Range C activities by a radiation protection personnel (who are not necessarily professionals). Since Range C exposures are generally routine and uniformly accumulated, direct supervision by a health physicist at each activity is not warranted. These activities can be adequately supervised by a radiologic technician under the oversight of a health physicist.

Two scenarios are presented in the cost analysis for option 2. The two scenarios vary in that they are based on different estimates of the size of the hospital in which five percent of exposures are anticipated to be in Range C. Five percent of exposures anticipated in Range C is judged to be sufficient to trigger the requirements of this guidance.

Scenario I includes all hospitals with nuclear medicine departments (about 3,700 institutions[1]), while scenario II only includes the 1,800 large hospitals (more than 200 beds) with nuclear medical departments. It is estimated that about 600 hospitals currently employ full-time health or medical physicists and supervise Range C activities, thereby satisfying the requirements of the guidance. These hospitals are expected to be large facilities. It is further estimated based on case study and related data that roughly 400 large hospitals employ a full-time health or medical physicist with duties other than radiation protection or exposure monitoring and that 500 hospitals retain part-time health physics consultants. None of these hospitals are believed to satisfy the supervisory requirement. In estimating the number of personnel necessary for compliance, the following assumptions were made:

- the services of part-time consultants would be subsumed by the impact of Range C requirements; therefore, they constitute an avoided expense in the cost estimate presented in Table 5;
- 75% of the 500 part-time consultants currently employed are associated with large hospitals;
- a health physicist already on staff currently devotes 10% of his time to non-supervisory tasks; this work would be delegated to a radiologic technician;
- small hospitals on average have only one department where Range C exposures are anticipated; therefore, one radiologic technician would be required;
- large hospitals on average have three departments where Range C exposures are anticipated; therefore, three technicians would be required;
- at large hospitals which currently monitor high-exposure activities, two additional technicians on average would be required;
- equipment such as survey meters, calibration sources, etc. required for a monitoring program would cost approximately $2,000.

Table 5 presents the calculation of costs for scenarios I and II under the above assumptions.

---

[1] *Estimates of total hospitals by category are rounded from Table 4 to reflect the few institutions not included in the American Hospital Association survey and changes since 1980.*

Scenario I estimates are:

Line 1 - 2,700 hospitals with nuclear medicine but without current HP staff

Line 2 - 6,800 HP technicians including 1 for each of 1,900 small hospitals with nuclear medicine; 2 for each of 600 large hospitals with nuclear medicine and a monitoring program; 3 for remaining 1,200 large hospitals with nuclear medicine and no monitoring programs; and 100 technicians to replace time of HP's who are now required to supervise the health physics program.

Line 3 - 3,100 hospitals with nuclear medicine and without a current radiation protection program.

Line 4 - 375 large hospitals with nuclear medicine and part-time HP service.

Line 5 - 125 small hospitals with nuclear medicine and part time HP services.

Scenario II estimates are:

Line 1 - 800 large hospitals with nuclear medicine and no health or medical physicists on staff

Line 2 - 4,900 technicians as in scenario I less 1,900 for small hospitals not included in scenario II

Line 3 - 1,200 large hospitals with nuclear medicine and no health physics program.

Line 4 - 375 large hospitals with nuclear medicine and part-time HP services.

Table 5: Hospital Cost Estimating for Range C Compliance

General Assumptions (Based on case study data)

1. Full annual cost of physican and health physicist (HP) = $68,000; (a base salary of $40,000, times a multiplier of 1.7 for overhead and fringe).

2. Full annual cost of radiologic technologist, diagnostic technician, and radiologic technician = $25,500, (base salary of $15,000 times 1.7 multiplier).

3. Annual cost of a radiation services consultant

   $4,200 — small hospital

   $7,800 — large hospital

SCENARIO I

	No. of Units	Cost	Annual Cost	Initial Cost
1. Full-time H.P. (+)	2,700	$68,000	183.6	
2. Technicians (+)	6,800	25,500	173.4	
3. Equipment (+)	3,100	2,000		6.2
4. Part-time H.P. services (-)	375	7,800	(2.9)	
5. Part-time HP service (-)	125	4,200	(.5)	
TOTAL			$353.6	6.2

SCENARIO II

	No. of Units	Cost	Annual Cost	Initial Cost
1. Full-time H.P. (+)	800	$68,000	54.4	
2. Technicians (+)	4,900	25,500	125.0	
3. Equipment (+)	1,200	2,000		2.4
4. Part-time H.P. services (-)	375	7,800	(2.9)	
TOTAL			$176.5	2.4

Guidance #5 - Anticipated Exposures in Range B (0.5 to 1.5 rem/year)

Range B exposures are anticipated at any hospital which has diagnostic radiology. Since all hospitals provide this service, the proposed guidance impacts on the entire industry. Compliance requires monitoring of Range B activities, and the availability of a radiation protection professional to assure exposures are justified and ALARA. Under scenario I from above, all hospitals with nuclear medicine would already have to hire a full-time health physicist. Therefore, only the 3,300 hospitals without nuclear medicine (all assumed to be small hospitals) would be required to hire a part-time consultant at $4,200 per year. The annual cost to the industry would be $13.9 million.

Under scenario II from above, the 2,000 small hospitals with nuclear medicine departments would have to retain a part-time consultant in lieu of responding to the guidance on Range C. However, 125 of these hospitals already employ a part-time health physicist. Therefore, a part-time consultant would be necessary at these 1,875 hospitals, as well as the 3,300 hospitals without nuclear medicine. At a consultant cost of $4,200 per year, annual industry costs would be $21.7 million.

If the guidance on Range C was not promulgated, then 325 additional large hospitals which currently employ neither full-time nor part-time health physicists would have to hire part-time consultants at $7,800 per year. The additional costs would be $2.5 million per year.

Table 6: Cost Estimate - Annual

Expense	Scenario I	Scenario II	In lieu of Range C
Part-time Consultant	$13.9 million	$21.7 million	$24.2 million

Guidance #6 - Training

It is estimated that 50 percent of hospitals with nuclear medicine currently satisfy the requirements on training in radiation protection principles and levels of risk. The other portion of the industry would have to provide two hours of additional instruction in levels of risk.

Instruction at hospitals not currently in compliance would be given by the full-time health physicist hired in response to Range C or by part-time consultants hired in response to Range B as an integral part of a total health physics program. Therefore, the costs of compliance are limited to the cost of staff time during training, a negligible cost which is not estimated here.

The industry has approximately 100,000 monitored and unmonitored workers with potential occupational exposure. It was noted above that approximately 50 percent of all radiation workers in hospitals with nuclear medicine departments already receive adequate training. The number of radiation workers by size of hospital or type of department is not available to estimate how many radiation workers at hospitals without nuclear medicine receive adequate instruction. It is assumed that half the radiation workers are in hospitals with nuclear medicine and half of these hospitals provide qualified instruction. Hospitals without nuclear medicine we assumed to not provide adequate instruction. It follows that 25% of radiation workers currently receive adequate instruction. The remaining 75,000 workers then must receive two hours of instruction at a full hourly rate of $10 per hour or $1.5 million.

If Range B and C were not promulgated instructor time would have to be added. Assuming 5,150 hospitals (1/2 of hospitals with nuclear medicine and all other hospitals with radiation workers 7,000 - 1,850) would have to hire consultants to provide 2 hours each quarter in levels of risk instruction at $250 per quarter total annual cost would increase by $5.1 million.

Guidance #7 - Exposure to the Unborn

Three alternatives are under consideration by EPA. Under Alternative a, women voluntarily keep the dose to the unborn to less than 0.5 rem during known and suspected pregnancy. All hospitals currently operate under this option. Therefore, there would be no impact if Alternative a were retained under the proposed guidance.

Under Alternative b, women able to bear children voluntarily avoid jobs with potential exposure in excess of 0.2 rem/mo., and keep dose to unborn less than 0.5 rem during known pregnancy. Since jobs with the potential exposures of 0.2 rem/mo. are considered the most rewarding, it is unlikely that many women would request transfer to low exposure jobs. Furthermore, a request for transfer from a small number of female workers at a large hospital would have negligible impact because the request could probably be accommodated by rotating staff. At small hospitals, however, a request for transfer could result in discharge. But again, assuming that few females ask for transfer, there would be no cost to the industry.

The other possible reason for compliance costs under Alternative b relates to exposure during pregnancy. But here as well, no impact is expected because the number of pregnant women at one time is too small. Assuming that the proportion of pregnant radiation workers is the same as the general female population (i.e., 6%), then only 4,000[1] women are potentially affected. The case studies indicate that staff rotation in larger facilities would permit most pregnant workers to remain on the job at low exposure activities. Assuming that 66% of pregnant workers are employed at hospitals capable of accommodating requests for transfer to low exposure jobs, then about 1,300 women would have to take leaves of absence without pay. This cost would not be borne by the industry, but by the individual. In summary, no cost to the industry is expected under Alternative b, both in regard to women able to bear children and women who are pregnant.

The impact of Alternative c depends on the form of monitoring. Under-the-apron monitoring is appropriate for measuring exposure to the unborn in cardiac catheterization and special procedures where the photon energies are relatively low. Since exposures measured under-the-apron are not usually in excess of 0.2 rem/mo. in these activities, these jobs would not be closed to female workers. Therefore, the impact of Alternative c with under-the-apron monitoring in departments other than nuclear medicine would be limited to the incremental costs of dual badging. Assuming that 2/3 of approximately 85,000 female radiologic technicians work at hospitals, then approximately 56,000 workers would be dual badged. Average badging costs are $15/year. Therefore, the total costs would be $840,000.

---

[1] *Assumes that 2/3 radiation workers are female (66,000 female workers times 6 percent is approximately 4,000 pregnant radiation workers).*

Table 7: Cost Estimate for Female Dual Badging

Expense	No. of female workers	Badging Cost/year	Annual Cost
Dual-badging	56,000	$15	$840,000

Dual badging would not provide the full protection for females in nuclear medicine because of the existence of some high energy photons which a lead apron may not provide the necessary protection. However, no case study hospital reported annual exposures in nuclear medicine of more than 2.5 rem/yr. and exposures in this department are accumulated relatively uniformly. Thus, exposures of 0.2 rem/mo. are not anticipated. It follows that jobs in nuclear medicine would remain open to females, which would impose no cost on the industry. Therefore, the compliance costs of Alternative c with under-the-apron monitoring is the costs of dual badging where appropriate.

However, if over-the-apron monitoring is considered the only acceptable way of measuring exposure to the unborn, women would be barred from high exposure activities other than nuclear medicine. To replace these workers, the number of male radiation workers would have to increase by a factor of 2 to 3. This is not feasible at this time. Moreover, female radiation workers would be deprived of their right to work, which may conflict with the EEO objectives of the hospital, and produce morale problems among staff.

Guidance #8 - Internal Exposures

Internal exposures in hospitals are likely to occur only in the preparation or use of nuclear medicines. The potential internal exposures from Tc-99m can easily be shown to be well within the 30 percent threshold for monitoring. Only radioiodine might require some monitoring and clinical uptake probes are readily available in all nuclear medicine departments. However, these instruments might require calibration, and the nuclear medicine technologists might require some outside assistance in performing the calibrations. It is estimated that one-half of the facilities requiring instrument calibration would use the services of a consultant at a cost of about $500. In addition, these facilities would require a phantom at a cost of about $200.

There are approximately 1800 NRC medical (non-private practice) licensees.[1] There are approximately 3,700 hospitals nationwide (Agreement and non-Agreement States) that have nuclear medicine departments.[1] It is estimated that only about one-third of the nuclear medicine departments in the country have quantitative internal exposure monitoring programs.[2]

---

[1] *Op. cit., NRC, NUREG-0714.*

Under the proposed changes, the scanning device would have to be recalibrated. This would constitute a one-time, initial cost. In addition, an average of two nuclear medicine technologists would have to receive instruction in self-monitoring during a one-hour seminar. (The average annual salary of a technician is $15,000.) These two services -- calibration and instruction — could be provided by a consultant hired at a cost of $500. Therefore, the costs of internal monitoring for the approximately 2,500 hospitals with nuclear medicine departments which are estimated to currently lack a bioassay program would be about $1.8 million.

Table 8: Cost of Internal Monitoring (Nuclear Medicine Departments)

Expense	No. of hospitals	Unit cost	Initial Cost
1. Part-time consultant	2,500	$500	$1,250,000
2. Staff time (2 hrs./ hospital)	2,500	$12/hr.	$ 60,000
3. Phantom	2,500	$200	500,000
TOTAL			$1,810,000

The one category of licensees that would require more extensive internal monitoring is the research hospital possessing a broad license. There are 95 NRC licensees in this category and an estimated equal number of Agreement State licensees. It is estimated that two-thirds of these have adequate bioassay programs.[3] Approximately 24,000 individuals who work for NRC licensees were monitored for external exposures in 1979.[4] Taking into account the number not reporting and Agreement State licensees, the total number of estimated employees in this category is 52,000. It is assumed, then, that approximately 17,000 are not monitored for internal exposure.

---

[1] *American Hospital Association, Hospital Statistics, 1981, p. 191-197, Table 12A.*

[2] *Bill Walker, U.S. Nuclear Regulatory Commission, private communication, September 1982.*

[3] *Ibid.*

[4] *Op. cit., NRC, NUREG-0714.*

Assume that a six-month program of internal monitoring is required to demonstrate that intakes are less than 30 percent of the limit. Assume that most of the researchers are handling tritium and P-32, and that 20 percent would be sampled to demonstrate that intakes are less than 30 percent the limit. Assume quarterly urinalyses at a cost of \$12/urinalysis.[1] The one-time cost would be 0.2 x 17,000 x 2 x \$12 = \$81,600. In addition, a small fraction of workers, say 10 percent, might be handling gamma emitters. Assume two whole-body counts are required on a sample of 20 percent of these researchers. At \$139 per whole-body count,[2] the one-time cost would be 0.1 x 0.2 x 17,000 x 2 x \$139 = \$94,520.

Therefore, the total cost for hospitals resulting from the internal exposure monitoring requirements are expected to be approximately \$2 million in start-up costs, with negligible continuing costs.

Guidance #9 - Alternative Annual Whole-Body Limit - 1.5/rem year

Assuming that exposures greater than 1.5 rem/yr. are anticipated at hospitals which have nuclear medicine, approximately 3,700 hospitals would be affected by the proposed guidance.

Compliance could be achieved in one of two ways, which constitute the upper and lower boundaries on cost:

(1) the imposition of a radiation protection program similar to the one at one of the case study medical centers,[3] which has an annual cost of \$340,000. (The full cost of the program is \$450,000, but 25% of its work is outside the facility.) Such a program would also have the benefit of decreasing collective dose.

---

[1] *Roland Finston, Stanford University, private communication, January 1982.*

[2] *Helgeson Nuclear Services, private communication, February 1982.*

[3] *Op. cit., Jack Faucett Associates, July 12, 1983, pp. 39-47.*

(2) an increase in the number of personnel in jobs with exposures in excess of 1.5 rem/yr. to reduce individual exposures, at the expense of an increase in collection exposure.

The first option entails the development of an extremely active health physics program that would not only reduce the likelihood of exposures in excess of 1.5 rem but would satisfy every intent of the proposed guidelines. This is not, however an inexpensive option. If the ideal program were applied to all hospitals with nuclear medicine departments and we assume that the program cost by size of hospital would vary as follows:

Table 9: Cost of Ideal Hospital Program

Hospital Size (bed)	Number in Category	Percent of Ideal Program Cost	Estimated Overall Cost (millions)
> 400	700	100	238
200-400	1,100	75	281
100-200	1,000	50	170
< 100	900	25	77
			766

This total could be thought of as the cost of all hospitals converting to an ideal program. These costs could be reduced somewhat over time as the program becomes established (10-15 years).

It is virtually impossible to identify the components of the ideal program cost associated only with the reduction of the annual limit to 1.5 rem/year. The administration of that program would argue that such reductions can only occur as part of a total program. It is not believed that all hospitals and radiation protection program administrators would be so zealous. Relaxing some standards, and concentrating the program on the annual limit could be expected to reduce the total cost of the ideal program by about one half or $400 million.

The alternative program would spread the collective dose over a larger number of workers. Approximately 2,200 employees are currently exposed to an excess of 1.5 rem/year[1]. If the high exposure staff could be doubled and if half of the additional workers are doctors and the other half are technologists, the average full cost of the additional worker (both physicists and technicians would be $59,500, and the costs to the industry would total $130 million. In addition, there would be an increase in collective exposure. (An estimate of the magnitude and cost of this increase in collective exposure is considered to be beyond the scope of this study.) It is, however, very uncertain whether the addition of staff as suggested would eliminate the exposures in excess of 1.5 rem/year. If such activity were possible, it would provide a less costly alternative to the suggested Range C costs.

---

[1] *Op cit., NRC NUREG-0714 and JFA estimates for NRC Agreement State Licensees.*

3.3 SUMMARY OF COST OF COMPLIANCE

The 5.0 rem/year and accumulated lifetime exposure limits would have no impact on the industry. The guidance on exposure to extremities and organs would also have no impact.

The proposed guidances for Range C (1.5 - 5.0 rem/yr.) and Range B (0.5 - 1.5 rem/yr.) would result in compliance costs, and these depend on the interpretation of the guidance. Under a strict interpretation of the guidance on Range C, all hospitals with nuclear medicine be required to respond. The annual costs to the industry would be $350 million after an initial outlay of less than $10 million. The annual costs for a liberal interpretation of the guidance, which encompasses only large hospitals (i.e. more than 200 beds), would be $ 170 million with initial outlays of $2 million. The continuing costs are primarily associated with additional health physics professional and technical staff.

The guidance on Range B affects all hospitals with diagnostic radiology departments, and therefore encompasses an estimated 7,000 hospitals in the industry. Since hospitals responding to the guidance on Range C also satisfy Range B, only the 3,300 hospitals without nuclear medicine departments would have to hire part-time consultants under the strict interpretation presented above. The total annual costs are estimated to be about $10 million. Under the liberal interpretation, small hospitals with nuclear medicine departments also would have to respond to Range B, and the total annual costs could reach $22 million. If Range C were not promulgated, total costs for Range B are estimated to be about $24 million.

The proposed training requirements are currently being satisfied, with the exception of instruction in quantitative levels of risk. It is estimated that to satisfy this additional intent, estimated costs are $1.5 million annually under the assumption that Range B and C are promulgated. If they are not, estimated instructor cost would be $5.1 million annually.

The industry currently operates under voluntary programs similar to or precisely the same as the unborn protection provided by Alternative a. Alternative b specifies that the women able to have children would voluntarily avoid jobs with exposure greater than .2 rem/mo. Few hospital workers would be affected by this alternative. The professionally rewarding nature of the potentially high exposure assignments (e.g., diagnostic radiography special procedures) would limit the workers requesting other assignments and thus only negligible costs to the industry are expected.

The costs of the mandatory provisions of Alternative c depend on the acceptability of under-the-apron badging. Such badging would eliminate assignments with recorded exposures in excess of .2 rem/mo. in radiography and cardiology. A second badge for each affected worker (assuming collar badge is still worn) would result in just less than $1 million cost. If such badging were not permitted for compliance, women would be barred from these activities and severe labor shortages would develop that could limit available services.

The proposed guidelines on internal exposure would require routine measurement of uptake of radioiodine during thyroid scans. The one-time costs for recalibrating the existing scanning devises; providing instruction in self-monitoring to an average of two technicians per hospital; and satisfying regulators that broad license holders would not require a program beyond that currently in use are expected to cost industry about $2 million.

Under the alternate 1.5 rem whole-body limit, two options are possible. One is a vigorous radiation protection program similar to that operated by one of the case study firms. Such an industry-wide program would satisfy all portions of the guidance. Based on the actual cost of such a program for the case study institution, a large medical center, the costs of compliance for all other hospitals of any size was estimated to be $400 million. The other option would be a doubling of the current staff to decrease individual exposure to less than 1.5 rem/year. The availability of labor to meet such an expansion is a serious limitation to this option.

CHAPTER 4

COST OF COMPLIANCE: PRIVATE MEDICAL PRACTICE

4.1 INDUSTRY PROFILE: PRIVATE MEDICAL PRACTICE

Census data for 1977 indicate a total of 189,143 physician offices in the U.S. generating receipts of $28.8 billion. In addition, there were 5,888 offices of osteopathic physicians ($776 million in receipts) and 14,343 chiropractor offices ($680 million in receipts) (U.S. Department of Commerce, 1977 Census of Service Industries: Health Services).

Performance and Services

Although specific data on the types of services available at private practice locations are not available, the range of services offered is estimated to be fairly large considering a trend to group practices and the degree of medical specialization. Estimates are also not available on the number of patients seen by private practitioners on a yearly basis. Many physicians are also affiliated with community hospitals, teaching hospitals, or medical centers which increases their potential caseload.

As such, estimates of the use of x-ray sources of radiation by private practitioners at their locations is also difficult to estimate. In 1970, when the Bureau of Radiological Health conducted its study on population exposure to X-rays, only 24 percent of fluoroscopic procedures were found to be performed out of hospitals.[1] Special procedures such as mylograms, cystography, hysterosalpingograms, and arteriography were found to be performed exclusively in hospitals in 1970. Although this situation may now have changed, more recent data are not available. Best estimates would place radiation exposures in private offices at 10 percent of those received in hospitals.

Somewhat better estimates are available concerning private practices in nuclear medicine. According to Nuclear Regulatory Commission (NRC) data,[2] there are approximately 300 NRC medical licenses in private practice. If 40 percent of all private practices are federally licensed, there may be an additional 450 private practices (for a total of 750) licensed by NRC Agreement States. It is estimated that there are no private medical offices in the U.S. with full-time radiation protection professionals. However, possibly as high as 20 percent of all private practices in nuclear medicine may retain consultants for licensing and radiation protection at a cost of approximately $100 per month[1]. Some training in radiation protection principles is likely received by workers employed by private practices in nuclear medicine.

---

[1] *David Johnson, Bureau of Radiological Health, private communication, January 26, 1982.*

[2] *Occupational Radiation Exposure, Twelfth Annual Report 1979, NUREG-0719.*

From an extrapolation of data compiled by the American College of Radiology, there were approximately 17,000 radiologists in 1980.[2] Fifty to sixty percent of these radiologists are estimated to be in private practices. On average a practice will have six radiologists on staff and operate 1.6 offices for a total of approximately 2,500 private radiology offices nation wide. As with private practices in nuclear medicine, full-time radiation protection professionals are likely not employed by private diagnostic radiology practices, however, unlike nuclear medicine practices, the use of consultants or in-house training programs is rare to non-existent.

Of the non-radiologists, specialists in orthopedics, chiropractors, and some urologists, gastroenterologists, and pediatricians also operate their own X-ray machines. Little data is available on these practitioners, however, it is unlikely that workers in these offices are uniformly instructed in the principles of radiation protection.

Employment

Of the 136,164 physician offices with payroll in 1977, total payments for wages and benefits totaled $11.9 billion in 1977. Census data show that 137,465 associate physicians ($8.2 billion in payroll), 6,101 nurse practitioners ($73 million in payroll), and 33,909 physician assistants ($277 million in payroll) were employed in private physician offices. In addition, 66,428 RN's ($567 million) and 43,118 LPN's ($290 million) were employed in physician offices. Sole practitioners and partners numbered 83,399 in 1977 (U.S. Department of Commerce, 1977 Census of Service Industries: Health Services).

---

[1] *Hugh O'Neil, Health Physics Services, private communication, January 13, 1982.*

[2] *Robert Harrington, American College of Radiology, private communication, February 1, 1982.*

Data on the number of radiation workers in private physician offices are not available. Estimates given in the preceeding section indicate that there are approximately 9,300 radiologists in private practice and perhaps as many as 750 - 1,500 physicians in the private nuclear medicine practices.

Only 13 states license technologists for private practices. Of those licensed technologists, those who work in radiation therapy or diagnosis are registered radiologic technologists and therefore have received formal training. In other states, workers may or may not be formerly trained in radiologic technology (McGowan, private communication).

4.2 COST OF COMPLIANCE WITH GUIDANCE

Private Medical

Guidance #1 - Annual Whole-body Limit - 5.0 rem/yr.

Sound health physics practice suggests that there should be no impact, and case studies and follow-up research confirms this. However, the 1975 EPA study[1] indicated that as many as 400 employees in this industry may have been exposed to doses greater than 5 rem. More recent data on exposure in nuclear medicine private practices reported to NRC[2] indicate that no exposure in excess of 3 rem occurred in 1978 or 1979. Improved health physics practices and risk awareness by both employers and employees should have reduced these high 1975 exposures at little or no cost. Thus, no impact from this revision to the guidance is anticipated. However, anxiety was expressed over the possibility that the 5 rem limit would constrain high-exposure frontier research.

Guidance #2 - Accumulated Lifetime Whole-body Exposure

There is no impact. Accumulated exposure for a technologist at one case study firm with 15 years of experience was an order of magnitude below the 100 rem limit.

---

[1] *Op. Cit., EPA, 1980, EPA 520/U-80-001.*

[2] *Op. Cit., NRC, NUREG-0714.*

Guidance #3 - Exposure to Extremities and Organs

There is no probable impact. There is no reason to believe that exposures to the eye are greater than whole-body exposures, therefore monitoring at the collar should be sufficient to measure exposures to both the whole body and the eye lens.

Doses to the hand have been as high as 2 rem/year. Most nuclear medicine private practitioners now use unit dosages prepared out-of-house, which should result in hand exposures 2 orders of magnitude below the 50 rem/yr limit.

Guidance #4 - Exposures in Range C (1.5-5.0 rem/yr.)

In general, private practitioners do not anticipate exposures above 1.5 rem/year. In the private practice of a case study radiologist, the highest annual exposure was 1.0 rem. In the case study practice of a nuclear physician, the average exposure was less. If these exposures are representative of the industry, there should be no impact. Again, the 1975 EPA study indicates that over 3,500 workers received between 1 and 5 rem in 1975. Utilizing the NRC exposure distribution[1] for its private practice licensees, it is estimated that approximately 700 of these exposures were in excess of 2 rem. It is believed that good health physics practice can eliminate all of these exposures at little or no cost. This position was supported by all knowledgeable industry persons contacted in case studies or subsequent research. Any activity that could result in high risk of unusual occupational exposure should be accomplished in a hospital setting.

Guidance #5 - Anticipated Exposures in Range B (0.5-1.5 rem/yr.)

Exposures in Range B can be anticipated in diagnostic radiology, and in the private practice of nuclear medicine, exposures are sufficiently close to 0.5 rem to anticipate exposures in this range. Therefore, a radiation protection professional would have to be available to assure that exposures are justified and ALARA.

If a nuclear physician or an experienced radiologist were considered equivalent to a radiation protection professional, this guidance would have negligible impact. However, if equivalence is not accepted, then the 2,500 radiology offices and 80% of the 750 private offices in nuclear medicine would have to employ part-time consultants at an estimated $100/month. The total cost would be roughly $3.72 million.

---

[1] *Op. Cit., NRC, NUREG-0714.*

Table 10: Cost Estimate Range B Requirements in Private Medicine

Expense	No. of firms	Cost/firm	Annual Cost
1. Part-time consultancy for radiology practices	2,500	$1,200	$ 3 million
2. Part-time consultancy for nuclear medicine practices	600	$1,200	$ .72 million
TOTAL			$3.72 million

Guidance #6 - Training

In most instances, training in radiation protection and levels of risk is received during formal education. However, to keep up with new developments in technology and procedure, an annual refresher course would be necessary. This instruction could be given by the part-time consultant hired to monitor Range B exposures and the cost would be included in the $1,200 per year fee. Therefore, the cost impact would be limited to the hour of additional staff time during instruction. It is assumed that all practices in radiology and nuclear medicine would be Range B establishments and thus all radiation workers would require instruction. Utilizing the employment figure from the 1975 EPA report for private medical practice overstates, to some degree, the number of employees who would require this instruction since other practices included (urology, pediatry, etc.) may include radiation workers who are not exposed in Range B. It is believed that the error in the assumption is slight. No exposure data on the other practices are available to refine the estimate. Given an average worker cost (salary plus fringe plus overhead) of $25,000, an additional hour of instruction for the 138,000 would cost $1.66 million.

Table 11: Cost Estimate for Training Requirements in Private Medicine

Expense	No. of workers	Cost/hour	Costs
Instruction	138,000	$12	$1.66 million

Guidance #7 - Exposure to the Unborn

Since private practitioners already conform to Alternative a, there would be no cost. And since hospitals, and not private practitioners, generally perform services with potential exposures greater than 0.2 rem per month, there would also be no impact under Alternatives b or c.

Guidance #8 - Internal Exposures

Internal exposures are anticipated in private practices of nuclear medicine, but not in those of radiology. Therefore, the impact is limited to the roughly 750 nuclear medicine practices. The radionuclide of principal interest is radioiodine. The thyroid scanning device, which currently is used to determine arrival of the radioisotope at the organ, can be recalibrated to detect and measure uptake to the administrating technologist. Recalibration would require hiring a part-time consultant who would instruct the technologist in self-monitoring during a one-hour seminar. The cost of the consultant is estimated to be $1,200 and the average salary of a technologist is about $15,000 ($25,000 including fringe and overhead). NRC data[1] indicate that there are approximately 7 monitored workers per practice and it is assumed that each would learn the required procedures. Total cost for this guidance is estimated to be about $1 million.

Table 12: Cost Estimate for Internal Exposure Requirements in Private Medicine

Expense	No. of Units	Unit cost	Initial Cost
1. Part-time consultant	750	$1,250/week	$ 937,500
2. Staff time (1 hr/worker) (7 workers/practice)	5,250	$12/hour	$ 63,000
TOTAL			$1,000,500

Guidance #9 - Alternative Annual Whole-Body Limit - 1.5 rem/year

The case studies and all contacts with knowledgeable industry professionals indicated that no activity undertaken in private medical practice should result in routine exposure in excess of 1.5 rem per year. While the 1975 EPA data indicate exposures in excess of 1.5 rem, it is believed that current exposures are lower than the 1975 data and that planning for reducing what few exposures greater than 1.5 rem now occur (NRC data indicate that about 0.5 percent of monitored workers in private practice were recorded in excess of 1.5 rem) should lead to only limited and localized cost. An example might be the replacement of an old x-ray machine with a new system that provides shielding and columnated rays. To the extent that such replacement occurs because of a 1.5 rem limit, the cost should be attributed to the guidance. However, these costs would have to be reduced by any benefit accrued to the establishment from the use of the new technology.

---

[1] *Op. Cit., NRC, NUREG-0714.*

4.3 SUMMARY OF COST OF COMPLIANCE

The levels of exposure in this industry are relatively low. Therefore, there would be compliance costs only for the proposed guidances on Range B, training, and internal exposure. The annual costs of hiring part-time consultants to monitor Range B exposures are estimated to be $4 million. To instruct workers on levels of risk would cost an additional $2 million annually. And to recalibrate thyroid scanning devices for measurement of internal exposure would involve an initial, one-time cost of $1 million. Therefore, the annual costs of compliance would be approximately $6 million, and the first year costs, would be $1 million.

CHAPTER 5

COST OF COMPLIANCE: INDUSTRIAL RADIOGRAPHY

5.1 INDUSTRY PROFILE: INDUSTRIAL RADIOGRAPHY

Industrial radiography is one of several processes utilized to test the quality of a product or service without destroying the object of the evaluation. One of the most common uses of these techniques is the evaluation of a weld. Building superstructures, ships and pipelines are areas where extensive welding must be evaluated without destruction of the property. Nondestructive testing (NDT) can be carried out by one in-house division. Engineering firms often offer NDT as part of a full service design, construct and test system. There are also many small firms with 2 to 50 employees that specialize in NDT. An NRC licensee or an NRC Agreement State Licensee is required to purchase and utilize the radioactive source material used to expose x-ray film.

There were 370 NRC licensees in 1979, mostly in the North, and roughly 500 NRC Agreement State licensees geographically concentrated in Texas and Louisiana. The larger firms usually maintain licenses with the NRC and one or more Agreement States. Therefore, an estimated 700-800 industrial radiography establishments are currently in operation.

Performance and Services

About half of all radiography performed is undertaken by in-house staff with the balance performed by contractors. Employees may be full-time radiographers, or they may be NDT technicians who work for testing firms where they perform various NDT tasks (i.e., ultrasonics, visual inspections, etc.). Radiography is performed in a variety of ways:

1. At the firm's facilities. Clients are urged to bring pieces to the firm's facilities to reduce costs. In this mode, a radiographer may work alone (others are available, should assistance be needed).

2. On-site radiography at short distances from the firms' facilities. A minimum of a two-man team, one of whom must be a licensed radiographer, is generally sent. For these relatively close jobs, film processing may be performed at the home facility, where an automatic film processor is used.

3. On-site radiography at relatively long distances from the firms' facilities. At these distances, a mobile darkroom and possibly an extra technician are generally sent with the team.

4. Radiography with the client's equipment. Only the people are sent. The client's sources and darkroom facilities are used.

Employment

The number of workers in this industry is not known precisely. In Louisiana, an NRC Agreement State, there are approximately 1,100 radiographers and assistants or approximately 15 per licensee. In 1979, there were approximately 13,000 individuals monitored among the NRC licensees, and NRC has about 40% of the total number of licensees. However, there are some firms licensed by both the NRC and NRC Agreement States; licensees in NRC agreement States appear to be smaller firms with about half as many employees on average as NRC licensees. Therefore, it is reasonable to assume that there are about 20,000 radiographers and assistants in the U.S. (15 per Agreement State licensee plus 35 per NRC licensee).

The number of field teams is also not precisely known. Several algorithms were proposed to obtain the number of teams in the field at any one time. One which is easy to apply to existing data and was suggested by a case study firm predicts that the number of field teams is equivalent to the number of radiographers (plus assistants) divided by five. Using this algorithm, we estimate that approximately 4,000 teams routinely operate at one time.

Workers in Texas and Louisiana typically start out very young and approximately 5% of radiographers plus assistants are female. There is a high rate of turnover and it is unclear how many remain in the field for more than 20 years because of the physically demanding nature of the work.

Appendix A to Part 34 of the NRC Rules and Regulations is very specific on instruction required in radiation protection principles. The Agreement States also conform to these guidelines.

5.2 COST OF COMPLIANCE WITH GUIDANCE

Industrial Radiography

Guidance #1 - Annual Whole-body Limit - 5.0 rem/yr

There is estimated to be no impact on NRC licensees. A potential for exposures in excess of the proposed annual limit exists at operating nuclear plants largely due to background exposure. Nuclear power plant licensees carry the responsibility for conforming to the regulation and thus exposures in excess of the proposed limits, if any, are included in the commercial nuclear power data base.

There may be significant impact to NRC Agreement State Licensees in the Gulf Coast Region, which includes approximately 250 firms in the States of Texas and Louisiana. Each of these firms would be expected to have at least one individual exposed to greater than 5 rem/yr. In Louisiana, there were 60 overexposures (greater than 3 rem/qtr.) in 1980 and out of 70 licensees in the State.

Cumulative exposures in industrial radiography are directly proportional to the number of radiographs obtained. Radiographers and radiographer's assistants are paid by the hour, so that their annual income is also proportional to the number of radiographs obtained. Therefore, the most direct affect of a curtailment in allowable annual dose is lower annual earnings for radiographers in the Gulf Coast Region. If additional radiographers were available to take up the workload, the result would be more employment, lower annual income per radiographer, and probably higher collective dose, but no apparent cost to the industry. However, the availability of additional radiographers is questionable and could lead to a less skilled workforce that could result in fewer operators per unit time. While no precise measure of the productivity change that might result is available, industry experts did not indicate that this was a major concern, since tasks are very repetitive and satisfactory skill levels can usually be reached.

The evidence of high radiographer utilization appears to be very localized, and may in fact be diminishing as the reduced level of activity in oil and gas exploration will require fewer hours of radiography.

Guidance #2 - Accumulated Lifetime Exposure - 100 rem

There is no quantifiable impact, although the guidance could limit the career length of a young person entering the field to 25 - 30 years. This career span, however, should be enough. Very few people are likely to stay active in industrial radiography beyond 45 - 50 years of age since it is physically demanding work. However, if an individual rises in the management chain, it may be necessary for him to receive exposure during the retrieval of a stuck source or some other comparable incident. This could have an impact on a very small group of individuals, and potentially limit the flexibility of some firms in the future. The cost impact, however, is not quantifiable.

Guidance #3 - Exposure to Extremities and Organs

The impact is negligible. Eye exposure is commensurate with whole-body exposure, and therefore is below the limit. Hand exposures are also well within the proposed 5.0 rem/year limit.

Guidance #4 - Anticipated Exposures in Range C (1.5 -5.0 rem/yr)

According to the NRC data base,[1] only 8% of the total number of industrial radiography personnel monitored receive exposures in excess of 1 rem/yr. Moreover, approximately one half of these exposures are likely to be less than 1.5 rem. These percentages, however, refer to the whole industry. Firms differ greatly in size, workload, and type of industrial radiography. From a conservative point of view, then, the larger and more active firms are expected to fall into Range C.

The proportion of firms in this category is assumed to be 25%. This percentage does not include industrial radiographers working at power plants, since the utility in these cases would have responsibility for compliance. While this number is only an estimate, it appears reasonable and consistent with all information collected in the case studies.

---

[1] *Op. Cit., NRC, NUREG-0714.*

There are approximately 750 firms and 20,000 radiographers in the industry. Strict interpretation of the guidance would require supervision of each field team by a health physicist. Using an algorithm derived from the two case studies which predicts one field team for every group of five radiographers plus assistants, it is estimated that there currently are 4,000 field teams in the industry. Assuming that only 25% of all firms fall into Range C, then 1,000 health physicists would be required.

This is not considered feasible for two reasons: first, excepting the largest establishments, supervision of each field team would likely bankrupt most firms. Second, assuming that the number of health physicists in the country is currently about 8,000[1], and furthermore, that they already are employed, it is unlikely that 1,000 health physicists are or would be available to this industry.

An alternative interpretation of the guidance would require each firm falling in Range C to have a full-time health physicist on staff, with monitoring responsibilities delegated to a radiographer on each field team. These radiographers would be qualified as radiologic technicians in a two-week seminar given by the full-time health physicists. It is also assumed that the regulations would provide enough lead time to allow training a quarter of the staff per year.

Under this interpretation, 187 firms would have to hire full-time health physicists and at least one radiographer per team would have to be qualified as radiologic technician. Assuming that one radiographer and one-half back up per team and an attrition rate of 25% for radiographers, the training program would be given to approximately 375 workers annually. Given a salary of $40,000 (full cost of $68,000) for a health physicist and an average salary of $25,000 ($42,500 full cost) for senior radiographers (team leaders), the annual costs would be approximately $13 million. This total takes into account the avoided expense of approximately $350 per month for the 150 part-time consultants currently employed by the most active firms in the industry.

---

[1] *Robert Alexander, U.S. Nuclear Regulatory Commission, private communication, January 13, 1982.*

Table 13: Cost Estimate for Range C Requirements in Industrial Radiography

Expense	No. of workers	Cost/firm	Annual Cost
Full-time health physicist (+)	187	$68,000	$12,720,000
Qualification of radiographers (+)	375	1,600	600,000
Part-time consultants (-)	150	4,200	630,000
TOTAL			$12,690,000

Guidance #5 - Anticipated Exposures in Range B (0.5 - 1.5 rem/yr)

All firms can anticipate Range B exposures, and therefore are required to monitor radiation workers and retain professional radiation protection supervision to assure exposures are justified and ALARA. The industry satisfies the former guidelines under NRC and NRC Agreement State regulations. Each firm also has a Radiation Safety Officer who assures exposures are justified and ALARA, but he is seldom a radiation protection professional. Therefore, a consultant would have to be retained by firms that do not anticipate Range C exposures. Assuming that approximately 563 firms fall into this category, and a cost of $350 per month for HP consultant services, the annual costs would be $2.36 million.

Table 14: Cost Estimate for Range B Requirements in Industrial Radiography

Expense	No. of Firms	Cost/ Consultant	Annual Cost
Radiation protection	563	$4,200	$2,360,000

Guidance #6 - Training

Training in radiation protection principles is uniform because of NRC requirements. Although the biological effects of high levels of exposure are included, the long-term stochastic effects are not. To include this would require an additional 2 hours of instruction for each worker beyond the current 16 hours.

Assuming that the full-time or part-time health physicist hired in response to the requirements for Range C and Range B would be providing instruction to workers as a part of his contract, the impact of the training requirement would be limited to the cost of staff time during instruction. The annual costs would be $800,000 for the 20,000 potentially exposed workers. The average salary of all workers is approximately $25,000 ($42,500 full cost).

Table 15: Cost Estimate for Training Requirements in Industrial Radiography

Expense	No. of Employees	Cost/ Employee	Annual Cost
Supplemental training (2 hrs)	20,000	$41.00	$817,307

Guidance #7 - Exposure to Unborn

There would be no impact. Firms under NRC and Agreement State regulation are currently operating within the guidance of Alternative a. Under Alternative b, there should be little difficulty in shifting pregnant workers to low exposure jobs. Under Alternative c, females would be barred from field work, which would curtail their freedom of choice. Their number at this time, however, is too small to have an impact on the industry.

Guidance #8 - Internal Exposures

There is no impact since all sources are sealed.

Guidance #9 - Alternative Annual Whole-body Limit - 1.5 rem/yr

Both case study firms felt that the lower whole-body limit would have a large impact on their workload and growth. While this may constitute a cost to an individual firm, it is not necessarily an industry cost if other firms were to pick up the slack.

However, the 1.5 rem/year RPG could limit the productivity of workers in high exposure jobs, which would be a cost to the industry. One way to estimate this cost is to estimate the number of additional employees necessary to perform the same amount of work and decrease individual exposure to less than 1.5 rem/year. We noted above that 8% of the workforce have annual exposures in excess of 1.0 rem. Taking a conservative estimate that one-third of these receive less than 1.5 rem/year, then approximately 5.4% of 20,000 workers receive annual exposures greater than the alternative annual limit. If this portion of the workforce is expanded in size by 50% to spread exposures over more workers, then 540 additional workers would be required, and the annual costs would be $23 million.

Table 16: Cost Estimate for Alternative Whole Body Limit for Industrial Radiography

Expense	No. of Workers	Cost/ Worker	Annual Cost
Additional workers hired to reduce individual exposure.	540	$42,500	$22,950,000

5.3 SUMMARY OF COST OF COMPLIANCE

The impact on industrial radiography is limited to the guidances on Range C, Range B, training, and the alternative 1.5 rem/year whole-body limit.

It is estimated that 25% of the approximately 750 firms in the industry would have to hire full-time health physicists to comply with the Range C guidance. The remaining firms would be required to hire part-time consultants to satisfy the requirements of Range B. The annual costs of these requirements are estimated to be $15 million.

Training in radiation protection principles is currently provided. To additionally instruct workers on levels of risk would cost approximately $800,000 annually for the 20,000 workers potentially exposed to radiation.

The impact of the alternate 1.5 rem/year limit would depend on the response of the industry. If other firms in the industry take up the workload of active firms whose growth would be limited by the 1.5 rem/limit, then there would be no cost to the industry.[1] However, if the active firms hire additional workers to lower individual exposures, productivity in these firms would decrease. This would produce a larger, less productive workforce at an annual cost of approximately $23 million.

---

[1] *This would, however, be a substantial economic impact, rearranging market structure, corporate performance and affecting job security.*

In summary, annual compliance costs in this industry could be $16 million if the 5.0 rem/year RPG were implemented. If the alternative 1.5 rem/year RPG was enforced, then the annual costs to the industry could total $23 million.

CHAPTER 6

COST OF COMPLIANCE: MANUFACTURE AND DISTRIBUTION OF LARGE SOURCES

6.1 INDUSTRY PROFILE: LARGE SOURCES

Gross sales in this industry were $25 million in 1981. There are five competitors which supply large radioactive sources to various industries. Several of these firms also manufacture and distribute small sources. Information relating to firms which are active in both markets was not available. The case study firm is principally involved in the production of cobalt sources, and less so in other segments of large source production. Therefore, it is not representative of the industry. Nevertheless, lacking sufficient information on its competitors, we assumed that the compliance costs for the industry were a factor of five greater than the costs for the case study firm. This procedure will have to be refined in the next part of the study. The case study firm has 80 employees, and all are monitored. Assuming that employment is roughly proportional to market share, then approximately 400 workers are potentially exposed in this industry.

6.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 — Annual Whole-body Limit - 5.0 rem/year

There would be no impact from this guidance. The case study firm voiced concern about the intangible costs related to public perceptions in the event of an accident. Thus restricting exposure to a low limit increases a risk of a legal overexposure and increased public scrutiny.

Guidance #2 — Accumulated Lifetime Whole-body Limit - 100 rem

The firm felt that compliance with the 100 rem limit could be accomplished at minimal costs. Some concern, however, was expressed about the potential for career shortening, but its impact is not quantifiable.

Guidance #3 — Exposure to Extremities and Organs

This guidance would have no cost impact at the case study firm, although some anxiety was expressed about being close to the limits on hand and eye exposures. Assuming that the guidelines can be satisfied with tighter monitoring, and that this applies to the other firms, then there would be no costs for the industry.

Guidance #4 - Anticipated Exposures in Range C (1.5 - 5.0 rem/year)

Exposures in excess of 1.5 rem/yr may be anticipated for personnel involved in three tasks. The first is source installation, which involves teams of three workers headed by an installer. In the course of a typical installation, an exposure of 50-75 mrem is expected.

Three options for compliance for installation of sources have been considered. The first involves qualifying installers as radiologic technicians in a two-week intensive course. The cost would include instructor time ($1,250/week) and staff time. In addition, it is assumed that the salary of the installers would likely be increased to $50,000 from $40,000 as compensation for additional responsibilities. Based on data provided by the case study firm, which controlled about 20% of this market, it is assumed that there are ten teams currently operating nationwide in five companies. The overhead and fringe benefit rate of the case study firm of 70% of labor cost will be assumed for all firms. While there is a high turnover rate for helpers, installers remain in their position for a reasonably long period of time. We will assume that one new installer per year must be qualified after the initial upgrading of the current workforce.

Table 17: Cost Estimate of Qualifying Installers as Health Physics Technicians

	Initial	Annual
Instructor for 2 weeks (5 companies initial year, 1 annually)	$12,500	$ 2,500
Staff time (2 installers initially, 1 annually)	32,700	3,270
Increased salary (no additional overhead)	100,000	100,000
Total	$142,200	$105,770

The second option entails an increase in the number of teams to reduce individual exposure to less than Range C. To be under Range C, the current workload of each team is estimated to be halved to 20 installations per year. Therefore, ten additional teams would be required.

This option could be more expensive than direct supervision by a health physicist at each installation. However, two other factors should be taken into account; first, the full cost of a health physicist who travels extensively could be significantly higher than the standard salary of a health physicist, which is $40,000 per year on average; second, the salaries of installers would be expected to decrease significantly if workloads were reduced by a factor of 2. Assuming that the revised salaries of installers and helpers are $10,000 less than their current level and an overhead and fringe rate of 70%, the annual costs to the industry of additional staff would be $680,000.

Table 18: Cost Estimate of Additional Installation Teams

	No. of Workers	Salary	Full Cost (1.7 overhead multiplier)
A. Additional workers			
(1) installers	10	$30,000	$510,000
(2) helpers	20	$20,000	$680,000
B. Avoided expense (-)	30	$10,000	(510,000)
Total			$680,000

Under the third option 10 to 15 full-time health physicists would be necessary to directly supervise source installations. Assuming their salary is increased to $50,000 as compensation for traveling, the annual costs would range from $850,000 - $1,275,000. These costs are greater than option 2 and since exposures are accumulated uniformly during installation, the direct full-time supervision of a health physicist may not be warranted. The first option satisfies the requirements at least cost and would be selected.

The two other areas where Range C exposures are anticipated are source fabrication and waste handling. These operations may involve significant exposures. Therefore, the supervision of a radiation protection professional would likely be required.

Although no health physicist is currently on staff of the case study firm, at least three members of the engineering staff, and possible as many as five, could potentially pass the health physics certification examination with several months of study. This approach would be a less costly approach than hiring two full-time health physicists. Moreover, experience has demonstrated that a newly-hired health physicist would contribute little until having spent roughly two years at the plant to become sufficiently familiar with its operation. Therefore, it is expected that the case study firm and the industry as a whole would prefer training its current staff.

Assuming that training would take three months for each engineer and that it would be staggered throughout the year because engineers are critical to the operation of the firm, then a full-time instructor would be necessary. The annual salary of an instructor is $25,000.

Table 19: Cost Estimate of Qualifying Health Physicists In-House At Large Source Manufacture

		Salary	Full Costs (1.7 overhead factor)
1.	Instructor (5 firms)	$25,000	$212,500
2.	Staff time (45 man-months)	$40,000	$255,000
	Total		$467,500

Assuming the cost from Option 1 for source installation and the estimated cost for health physics supervision in waste handling and source fabrication, the total cost of the Range C guidance would be an initial cost of $145,200 and an annual cost of $573,270.

Guidance #5 - Anticipated Exposure in Range B (0.5-1.5 rem/yr)

All personnel potentially exposed in excess of 0.5 rem/yr. are currently monitored for whole-body exposure. The firm also retains a medical physicist as a consultant, but he does not perform hands-on monitoring or assure that exposures are ALARA. These functions could be performed by the group of health physicists who are hired or trained in-house to satisfy the guidance on Range C. Therefore, the costs of monitoring would be subsumed under Range C.

Guidance #6 - Training

Each new employee is given a briefing of approximately two hours duration on radiation protection principles. This briefing does not include quantitative guidance on levels of risk. Nor does the NRC Regulatory Guide 8.29 "Instruction Concerning Risks from Occupational Radiation Exposure", which has been recently distributed to all radiation workers. Therefore, an additional hour of instruction to all radiation workers would be necessary.

Since a full-time instructor would be hired to qualify three engineers as health physicists under Range C, the impact of a training program would be limited to the costs of staff time taken up during instruction. At an average salary of $20,000 and an overhead rate of 1.7, an hour of additional instruction for the 400 radiation workers would cost for the industry approximately $6,400.

Table 20: Cost Estimate for Training Requirements in the Manufacture and Distribution of Large Sources

Expense	No. of workers	Cost/hr	Annual Costs
Staff time (1 hr/worker)	400	$16	$6,400

Guidance #7 - Exposure to Unborn

There would be no impact because females are not employed for tasks where exposures may be received in excess of 0.5 rem/9-month period, or in excess of 0.2 rem/month.

Guidance #8 - Internal Exposures

Five individuals at the case study firm are potentially exposed from inhalation of airborne activity, and there is no existing internal dosimetry program. Assuming that the other firms in the industry also lack internal dosimetry, then approximately 25 individuals would have to be monitored quarterly for internal exposure. The estimated cost per count (for 1 to 10 individuals) is \$169.[1] Therefore, quarterly counts for 25 workers would cost approximately \$17,000 annually.

Table 21: Cost Estimate for Internal Exposure Requirements in the Manufacture and Distribution of Large Sources

Expense	No. of workers	Cost/ count	Cost
Quarterly counts	25	\$169	\$ 17,000/yr.

Guidance #9 - Alternative Annual Whole-Body Limit - 1.5 rem/year

For the case study firm 34 man-rem of collective exposure were accumulated in 1981 above the exposure level of 1 rem/year, which is the assumed administrative limit for an annual limit of 1.5 rem. In order to reduce this man-rem to below the limit (administrative limit times number of workers with productivity loss)[2] an additional 25 workers would have to be hired and a 12% increase in total man-rem would be expected. Assuming the industry would require 125 workers at a full cost of \$34,000 per year, total cost would be \$4,250,000 annually. As no exposure above 1.5 rem would now be anticipated, costs for Range C would be eliminated. Thus the net cost of the 1.5 rem whole-body limit would be about \$3,750,000 annually with an additional savings of about \$150,000 in the initial year.

---

[1] *Helgeson Nuclear Services, private communication, February 22, 1982.*

[2] *See Chapter 11 of this report for detailed description of methodology (page 85).*

6.3 SUMMARY OF COST OF COMPLIANCE

The compliances costs of the case study firm have been generalized to the five firms in the industry. These costs relate to the requirements on Range C, instruction on levels of risk, internal exposure, and the alternative annual whole-body limit.

Several options were considered for minimizing the cost of Range C compliance. It is believed that training current staff to qualify as health physics professionals who could monitor the high exposure activity would result in the lowest compliance cost of $150,000 in initial cost and $600,000 in annual costs.

Instruction on levels of risk for the industry's 400 potentially exposed workers would cost approximately $6,000 annually. An internal dosimetry program for the industry's 25 workers with potential internal exposure would cost approximately $17,000 per year. Finally, to reduce individual exposure to less than 1.5 rem/year would require an expansion of 125 in the number of workers in the industry and an annual cost of about $4 million.

CHAPTER 7

COST OF COMPLIANCE: MANUFACTURE AND DISTRIBUTION OF SMALL SOURCES

7.1 INDUSTRY PROFILE: SMALL SOURCES

The principal uses of small radioisotopes are research and clinical diagnostic products for the sciences. In the research products line, chemicals are labeled with C-14, H-3, S-35, P-32 (all beta emitters), I-131 and I-125 (gamma emitters). Additionally, small calibration sources (less than 100 mCi) are manufactured from as many as 100 isotopes. The predominant radioisotopes in the clinical diagnostics' line are Mo-99 (for generation of Tc-99m), Tl-201, Ga-67, and Xe-133. Isotopes are made by nuclear transmutation using cyclotrons, reactors, and accelerators.

Most of the higher exposures are experienced in four activities. These are production of Mo-99 generators, production and maintenance on accelerators, waste management, and transportation of radioisotopes. A transportation industry, mostly truck, services the industry. There are an estimated one million shipments of Mo-99 generators annually. An estimated 200 - 500 individuals who transport radioisotopes may be receiving non-negligible exposures.

The industry does not manufacture large, multi-curie sources for purposes of irradiation or radiography (i.e., Co-60, Ir-192, etc.). These are all reactor-produced sources. Another segment of the radioisotope manufacturing industry makes tritium signs, smoke detector sources, etc. This industry incorporates a number of small firms, has few employees and is thus neglected in this case study.

Gross industry sales are approximately $175 million. The industry is comprised of five major firms, one of which serves 50 percent of the market. The number of employees and potentially exposed workers are known, only for the largest firm, which has 1,700 total employees and 1,300 workers with potential exposure. Assuming that employment is proportional to market share, then the number of radiation workers in the industry is approximately 2,600.

7.2 COST OF COMPLIANCE WITH GUIDANCE

The unit cost assumptions utilized in this section are:

full-time health physicist (annual)	=	$68,000 ($40,000 salary x 1.7 - fringe + overhead)
health physics technician (annual)	=	$37,400 ($22,000 salary x 1.7 - fringe + overhead)
trucker (annual)	=	$25,000
truck (initial)	=	$30,000
truck (operating)	=	$64,000 (90,000 miles/yr)
radiation worker (annual)	=	$34,000

Guidance #1 - Annual Whole-body Limit - 5.0 rem/year

The case study facility currently operates under a self-imposed limit of 5.0 rem. However, to have an adequate safety margin of 20% under a regulatory limit of 5 rem, the firm would operate with an administrative limit of 4 rem/year. There are two possible strategies for achieving the 4.0 rem/year limit.

(a) hire additional radiation protection staff to tighten radiation protection procedures and increase monitoring;

(b) hire additional workers to reduce individual exposure to less than the annual 5 rem limit

If the firm chose to expand its radiation protection staff, then the costs would be subsumed by the costs of hiring full-time health physicists in response to the guidance on Range C.

If the firm expanded technical staff to reduce individual exposure, approximately eight additional workers are estimated to be necessary. This is an increase of 50% in the 16 workers estimated to have received annual exposures in excess of 4.0 rem. Assuming a full cost per worker of $34,000, the respective costs to the firm and the industry would be $272,000 and $544,000 respectively. In addition, there is estimated to be an increase in collective exposure of up to 10%.

Guidance #2 - Accumulated Lifetime Exposure - 100 rem

There is some potential for career-shortening. This would happen only in rare cases for technicians who start out at an early age and continue with the firm for more than 20 - 25 years in high exposure jobs. The quantification of costs to the industry is extremely difficult, depending on the availability of technicians.

Guidance #3 - Exposure to Extremities and Organs

There would be no problem in satisfying the requirements on hand exposure. The case study firm did express anxiety about eye exposure. However, it was believed that tighter surveillance and tightening of procedures would remove the potential for eye exposure above the proposed limit.

Guidance #4 - Anticipated Exposures in Range C (1.5 to 5 rem/yr)

Approximately 10% of the monitored employees at the case study firm may have been in Range C in 1980 and 1981. Five activities would contain essentially all of these personnel. They are:

(a) Accelerator maintenance — Supervision of the four cyclotrons, which operate on 24-hour shifts, would require six individuals. One technician is currently responsible for monitoring on a spot-check basis.

(b) Production of Mo-99 generators — Exposures are accumulated relatively uniformly. One supervisor could cover this room. A technician currently monitors its operations.

(c) Waste handling — Exposures as high as 100 mrem can be received during a single task. The area is currently monitored by a technician.

(d) Hot processing — Exposures of 100 mrem can be received during a single task. One supervisor would be required.

(e) Delivery of Mo-99 generators — The firm currently employs 20 truck drivers who load and unload sources. At any one time, as many as 300 shipments may be in progress.

Cost estimates are given for a strict and a liberal reading of the proposed guidance. For the strict interpretation, a radiation protection professional must be present at each high exposure activity. Under a liberal interpretation, a health physicist would only be required to supervise activities where a significant fraction of the annual limit exposure could be received during a single task, and not for activities where exposure are uniformly accumulated during the year. In the latter case, a radiologic technician would be adequate as long as a professional supervisor was immediately available. This applies to the production of Mo-99 generators, although not for hot processing and waste handling, where high exposures can be received during a single task. For maintenance of the four cyclotrons, a health physicist could supervise a team of health physics technicians. Since maintenance is a 24-hour activity, two professionals would be required.

The fifth high exposure activity is delivery of Mo-99 generators. It would be impractical to assign a health physics personnel to each truck. Exposures are uniformly accumulated and the cost would be prohibitive. An alternative to supervision is a reduction in individual exposure to a level where Range C exposures would not be anticipated. This could be accomplished by increasing the firm's trucking staff by 50% and its fleet by five trucks.

The following cost tabulation applies to the case study firm, and is presented for a strict and liberal interpretation of the guidance.

Table 22: Number and Type of Personnel Required in the Small Source Case Study Firm

	Strict Interpretation	Liberal Interpretation
Accelerator	6 health physicists	2 health physicists 5 radiologic technicians
Mo-99	1 health physicist	1 radiologic technician
Waste	1 health physicist	1 health physicist
Hot processing	1 health physicist	1 health physicist
Trucking	10 truckers 5 trucks	10 truckers 5 trucks
TOTAL	9 health physicists 10 truckers 5 trucks	4 health physicists 6 radiologic technicians 10 truckers 5 trucks
Less (-)	3 radiologic technicians	3 radiologic technicians

Table 23: Cost Estimate for the Small Source Case Study Firm

Expense	Strict	Liberal
Health physicists	$ 612,000	$ 272,000
Radiologic technician	—	$ 204,000
Trucking (operating)	$ 570,000	$ 570,000
Trucks	$ 150,000	$ 150,000
Minus: Current workers	$ 102,000	$ 102,000
Annual	$1,080,000	$ 944,000
Initial	$ 150,000	$ 150,000
Annual (Industry)	$2,160,000	$1,888,000
Initial (Industry)	$ 300,000	$ 300,000

Guidance #5 - Anticipated Exposure in Range B (0.5 - 1.5 rem/yr)

Both the monitoring and supervision requirements of this guideline are currently being satisfied by the radiation safety officer. Therefore, there would be no impact.

Guidance #6 - Training

This is currently carried out, including instruction on levels of risk.

Guidance #7 - Exposure to the Unborn

No industry costs are expected. If women were discharged under Alternatives b and c, the impact would be the negligible cost of rehiring and training male workers. Since only 10% -20% of technologists are women, their replacement with males should present no difficulty. This, however, could conflict with the EEO objectives of the firm.

Guidance #8 - Internal Exposures

No additional dosimetry would be required. However, the mechanics of compliance would require a computerized accounting system. This system could be programmed with approximately four person-months of effort. Assuming a yearly salary of $30,000 for a programmer, the initial, one-time industry costs would be $34,000.

Table 24: Cost Estimate for Internal Exposure Requirements for Small Source Manufacture

Expense	No. of firms	No. of months/ firm	Programmer cost/year	Initial Cost
Programmer	2	4	$51,000	$34,000

Guidance #9 - Alternative Annual Whole-body Limit - 1.5 rem/yr

Two drastic alternatives exist to reduce exposures to less than 1.5 rem/year: either the addition of expensive equipment or an expansion in the workforce. Since an estimate of the total costs of equipment was not available, only an estimate for the second option is presented. Utilizing data from the case study firm, it is estimated that approximately 50 additional workers at a salary of $20,000 per worker would be required. The annual cost of this option would be $1.7 million for the case study firm and approximately $3.4 million for the industry. However, the reduction in individual dose would be accompanied by an increase in collective dose of 10% - 20%.

Table 25: Cost Estimate for the Alternate Whole-body Limit for Small Source Manufacture

Expense	No. of firms	No. of workers/ firm	Full worker cost/yr	Annual cost
Additional workers	2	50	$34,000	$3.4 million

7.3 SUMMARY OF COST OF COMPLIANCE

The principal costs of compliance involve an increase in personnel in response to the 5 and 1.5 rem limits on annual whole-body exposure, and to the guidance on Range C. In addition, a computerized accounting system would be necessary to monitor internal exposures.

The impact of the 5.0 rem/year RPG will depend on whether the industry decides to increase radiation protection activities, or lower individual exposure by expanding the portion of the workforce receiving exposures in excess of 5 rem/year (and consequently increasing collective dose). The impact of the first option has not been estimated since it is subsumed in the response to the guidance on Range C. The total costs of the second option, expansion of the affected workforce by 50%, is estimated to be about $550,000.

The guidance on Range C would require supervisory personnel in four activities where annual exposures are anticipated in excess of 1.5 rem/year, and an expansion in the number of drivers and trucks to reduce individual exposure in transport of sources to less than 1.5 rem/year. The compliance costs of these requirements would depend on the interpretation of the guidance. A strict interpretation would require that all supervisory personnel be radiation protection professionals, whereas a liberal interpretation would allow delegation of supervisory responsibilities to radiologic technicians for activities where exposures are accumulated uniformly. The respective annual costs of the two interpretations are about $2 million with about $250,000 higher cost for the strict interpretation. There would also be initial costs of $300,000 for 10 additional trucks under both interpretations.

The third impact of the guidelines relates to internal exposure. The mechanics of compliance would require a computerized accounting system. The initial, one-time costs to the industry for programming are estimated to be $34,000.

The final impact relates to the alternative 1.5 rem/yr. whole-body limit. Two alternatives exist to satisfy this requirement: replace existing hardware or an expansion in the workforce. A cost estimate of the first option is not available. The second option would cost the industry $3 million per year.

CHAPTER 8

COST OF COMPLIANCE: DENTAL PRACTICE

8.1 INDUSTRY PROFILE: DENTAL PRACTICE

According to data from the Bureau of Census, there were 99,289 dental offices in the U.S. in 1977 generating $10 billion in receipts. Only 82,739 offices report a payroll and of this total, 59,811 are sole practitioners. Partnerships numbered 2,675 in 1977 and an additional 20,253 were classified as professional service organizations (U.S. Department of Commerce, 1977 Census of Service Industries: Health Services).

The membership directory of the American Dental Association (ADA) shows 117,000 dentists practicing in 1979 in the U.S. (ADA, 1982). Out of 6,416 dentists responding to an ADA survey, the ADA estimates that 87.9 percent of the total dentist population are general practitioners while 12.1 percent can be classified as specialists. Approximately 73 percent of all dentists work as solo practitioners, according to the ADA, i.e., they work without other dentists in the same practice. Seventy-three percent of all dentists also are sole proprietors of their practices. Most of these (91.9%) are general practitioners while only 8.1 percent are specialists. Only 4 percent of all dentists work in a partnership arrangement (85.1% are general practitioners) with 61.8 percent working with one other dentist, 24.1 percent with two, and 14.0 percent, working with four or more dentists (ADA, 1982). Some 25 percent of all dentists are shareholders in an incorporated practice. An estimated 1.7 percent of all dentists are female.

Performance and Services

According to the ADA survey, 32 percent of all single dental practices treat between 40 and 59 patients per week. Some 25 percent of the "solo dentists" see between 60 and 79 patients per week. The median number of patients per week for all solo dentists is 59.5 (ADA, 1982). Specialists tend to see more patients per week (79.7) compared to general practitioners (55.3) and the average number of patients seen per week increases as the number of dentists in a single practice increases.

ADA survey respondents reported that an average of 43.1 hours per week are spent on activities associated with the primary practice. An average of 33 hours is spent treating patients and 2.5 hours on laboratory procedures.

Dental services offered are quite specialized including periodontistry (1.5% of all specialists), orthodontics (5.1%), dental surgery (2.8%), endodontistry (0.8%), pedodontistry (1.5%), prosthodontistry (0.4%), in addition to the general dentistry practitioners. The use of x-rays is common to all these services. X-rays administered to patients include the Panorex or "full view" exposure of the mouth in addition to the limited view exposures of some portion of the mouth. Full view exposures are generally taken of the patient's mouth only once at the start of treatment as a new client. Limited exposure x-rays may be taken several times over the course of treatment, but, in recent years it has been recommended that the number of these exposures be limited and proper protection equipment and practices employed.

In recent years with the onset of advertising by dentists, the trend has been towards multi-chair, full service dental operations so that with increased client volume it is possible to achieve economies of scale. An average weekday patient load at such a facility can number from 150 - 200 patients of which 20 - 30 may be first-visit patients. ADA estimates show that 10 percent of all practices are multi-chair (more than 3 dentists) facilities.

In addition, dental services are offered in hospitals, both federal and non-federal. American Hospital Association survey results show 3,695 of all registered hospitals (59 percent) providing dental services, including 2,986 community hospitals (56 percent) (Hospital Statistics, 1981).

Employment

Census data for 1977 show that 27,666 associate dentists were employed in dentist offices in 1977 for a total payroll of $1.4 billion. Dental hygienists, technicians, and assistants numbered 44,851, 8,130, and 131,329, respectively. A 1975 occupational exposure survey estimated a total 265,700 dental workers in the U.S. of which 15 - 20 percent were potentially exposed to radiation (EPA, 1980). A typical multi-chair facility may employ 30 - 35 individuals of which one-half to two-thirds could be identified as radiation workers. These include, for the most part, the dentists themselves and their dental technicians. The ADA survey shows that 5.5 percent of all solo dentists employ no auxiliary personnel, 60.5 percent employ 1 to 3 persons, while 34 percent employ 4 or more auxiliary personnel. Somewhat more than half of all dentists (54.9%) employ one chairside assistant. ADA survey results show that hygienists are paid, on average, a higher weekly salary ($270) than other auxiliary personnel. Over 38 percent of all dentists employ a dental hygienist (ADA, 1982). Full-time hygientists reportedly treat an average of 41.5 patients per week.

8.2 COST OF COMPLIANCE WITH GUIDANCE

The dental industry employs the largest workforce of radiation workers. There is, however, no reason for these workers to be exposed to any substantial radiation doses. Health physics practice for this industry has improved steadily over the past decade. Practices even the most active, that follow basic safety procedures should have no measurable exposure and should experience no costs as a result of the guideline. Some practices may require investment to replace older equipment, but these costs are not a result of the guidance and are required by current regulations.

The case study firm was a large urban practice with over 30 dentists and staff. The facility utilized 12 x-ray machines, most of which are about 20 years old. The facility sees over 1,200 patients per week. This facility's records indicate that almost all staff receive less than measurable exposure. The only measured exposures over the past several years were attributed to the exposure of a badge attached to a lab coat left in an x-ray room for several days.

CHAPTER 9

COST OF COMPLIANCE: WELL LOGGING

9.1 INDUSTRY PROFILE: WELL LOGGING

Well logging is a geophysical technique frequently used in energy and mineral exploration to determine various subsurface rock properties in order to assess an area's mineral/energy potential. Its predominant application is in oil and gas exploration. Instruments are lowered into shafts down to depths of up to 35,000 feet and non-destructive measurements, read at the surface, are made over the entire length of the shaft. Measurements of electrical resistivity, gamma-ray attenuation, density, magnetic susceptibility, and sonic attenuation and travel time are made in order to assess such rock properties as porosity, permeability, fluid content, and the geometrical configuration of the reservoir. Two of these measurements involve the use of radiation sources, encapsulated in stainless steel, handled by the well-logging field team.

Performance

In 1977, well surveying and logging receipts for the oil and gas field services sectors totaled $556.5 million, up from $141.4 million in 1972 (DOC, Census of Mineral Industries: Oil and Gas Field Services, 1977). Estimates place the number of well-logging firms in the U.S. at 200 to 300 with the largest five of these performing about 80% of all well-logging services. In 1978, the Nuclear Regulatory Commission (NRC) licensed approximately 80 firms. Agreement states like Texas and Louisiana (where well-logging services are concentrated) currently license some 70 and 35 well-logging firms, respectively.[1] Many of these firms are relatively small operations. It is unclear what effect the current recession will have on the number or profitability of firm.

---

[1] *Joseph Gorell, Radiation Control Office, State of Texas, private communication, January 18, 1982.*

Employment

Total employment in the well-logging industry is estimated to be 25,000. Some 2,600 professional well loggers in the U.S. are members of the Society of Professional Well Log Analysts (more than 3,000 worldwide) with membership, only a fraction of all practitioners, increasing rapidly.

The heart of a well-logging operation is the field team, each typically comprised of three members — two operators and a field engineer. In the larger firms, there may be as many as 700 such field teams performing roughly 400 jobs per day. Training requirements, particularly for the field engineers, are substantial with instruction in radiation protection principles required and information on quantitative levels of risk soon to be added. Operators are usually not formally trained.

9.2 COST OF COMPLIANCE WITH GUIDANCE

Well Logging

Guidance #1 - Annual Whole-body Limit - 5.0 rem/yr

There is no impact from this guidance. It appears that the case study firm, an NRC licensee, is representative of the industry on occupational exposure. Given that it would have no problem in compliance, the same conclusion can be generalized for the entire industry.

Guidance #2 - Accumulated Lifetime Whole-body Exposure - 100 rem

Assuming that the case study firm is representative of the industry, no impact is expected.

Guidance #3 - Exposure to Extremities and Organs

Exposures to extremities are not greater than whole-body exposures. Therefore this guidance would have no impact.

Guidance #4 - Anticipated Exposures in Range C (1.5 - 5.0 rem/yr)

The distribution of exposures for a case study firm indicates that less than 10% are in excess of 1.0 rem/yr., and a large proportion of these probably fall between 1.0 and 1.5 rem. Moreover, exposures are accumulated relatively uniformly throughout the year. Therefore, it is unlikely that a "significant" contribution to the annual exposure would be accrued in the course of a single task. Nevertheless, from a regulatory standpoint, a conservative view is likely to be taken, and therefore Range C exposures would be anticipated.

Depending on the definition of supervision, there are three options for compliance. The strict, high-cost interpretation entails supervision by a health physicist at each field site. This approach is not feasible for several reasons. First, direct supervision by a radiation protection professional at each field site as well as the firm's headquarters and factory would require between 2,500 - 4,500 health physicists for the industry. The current national pool of health physicists could not satisfy this demand. Second, a full-time professional for each field team would put most small firms out of business. Third, it is unlikely that direct supervision by a health physicist would improve the level of radiation protection at an individual site. If a problem involving a potentially high exposure were to occur during the 30 to 90 seconds when the source is exposed, the proper action would depend on an assessment of risk in continuing the operation, which requires an engineer's knowledge of well-logging.

The medium-cost option would entail the employment of two full-time health physicists at each of the five firms that dominate the industry, and a full-time health physicist at each of the small firms. Monitoring responsibilities at all firms would be passed on to the crew chief of each field team, who would be qualified as a radiologic technician. The least-cost interpretation differs from the medium-cost approach in requiring only part-time health physicists at small firms.

The medium-cost approach could also place small establishments out of business. Substituting part-time consultants for full-time professionals would probably be economically feasible, but may not satisfy the intent of the guidance.

Qualification of an engineer as a radiologic technician under the medium and least-cost options could require two weeks of instruction, which would be given by the health physics personnel at each firm. With approximately 4,000 field engineers in the industry at any one time, and an industry turnover rate of one-third, 1,350 workers would receive training annually, assuming that the lead time provided by a regulation would allow training only new personnel. A new field engineer earns about $30,000 per year and a typical industry overhead rate is 70 percent of salary.

In summary, if full-time health physicists are required at small firms (although not at each field site), then the annual industry costs of additional staff and instruction of field workers would be $23.5 million. Alternatively, if consultants are permitted to fulfill the supervisory requirement on a part-time basis, and also give instruction to field engineers, then the annual costs to the industry would be $4 million. The cost impact of the high-cost option has not been estimated because this approach would not be feasible.

Table 26: Cost Estimate for Range C Requirements for Well Logging

(a) Medium-cost option — full-time health physicists required at all firms

Expense	No. of personnel	Full Cost/worker[a]	Cost
1. Instruction of engineers (staff time)	1,350	$ 2,000	$ 2.7 million
2. Full-time health physicists	260	$68,000	$ 17.7 million
TOTAL			$ 20.4 million

(b) Least-cost option — part-time health physicists permitted at small firms

Expense	No. of personnel	Full Cost/worker[a]	Cost
1. Instruction of engineers (staff time)	1,350	$ 2,000	$ 2.7 million
2. Part-time health physicist	250	$ 6,000	1.5 million
3. Full-time health physicists	10	$68,000	.7 million
TOTAL			$ 4.9 million

[a] Data on case study firm suggest an overhead and fringe multiplier of 1.7.

Guidance #5 - Anticipated Exposure in Range B (0.5 - 1.5 rem/yr)

The monitoring requirements are currently being carried out. The supervision requirements are not. However, the costs of satisfying the Range B requirements would be subsumed by the Range C requirements. If Range C were not promulgated, the 300 firms in the industry would have to hire a health physics consultant at an estimated cost of $300,000 per year.

Guidance #6 - Training

Two hours of instruction would have to be given to all field operators. However, supervisory personnel would already receive training in response to the guidance on Range C. Thus, approximately 10,000 (approximately 4,500 field teams with 2 or more operators per team) operators would have to be trained. Assuming a turnover rate of 1/3, then approximately 3,300 operators would receive two hours of instruction annually from health physics personnel at the firm. At an average salary of $25,000 per operator and a 70 percent overhead and fringe factor, the total cost of staff time during instruction would be $132,000.

Table 27: Guidance Estimate for Training Requirements for Well Logging

Expense	No. of workers	worker	Cost
Staff time (2 hrs/worker)	3,300	$40	$132,000

Guidance #7 - Exposure to Unborn

It is estimated that there is minimal cost to the industry under the three alternatives. If procedures are strictly followed in the field, exposures can be limited to less than 0.5 rem in nine months. Moreover, pregnant females are unlikely to work in the field for more than six months because of heavy lifting requirements. Therefore, Alternative a would impose negligible costs both for the industry and female workers. But if pregnant females chose to remove themselves from the field under Alternative a, they would probably lose their jobs.

Alternative b would likely have negligible impact on the industry since exposures in excess of 0.2 rem/mo. are highly unlikely. But again, as under Alterntive a, women requesting removal from the field would probably be discharged.

Alternative c would bar pregnant women from field work if the 0.5 rem limit were strictly adhered to. But given the small size of the female workforce in the field, the industry would incur no costs. Therefore, the primary impact would be on freedom of choice of females and the EEO objectives of the firm.

Guidance #8 - Internal Exposures

No cost impact is expected. Only one radionuclide with potential for internal exposures is used, and at a level of radioactivity well below the amount set by the NRC which would require bioassays.

Guidance #9 - Alternative Annual Whole-body Limit - 1.5 rem/yr

Exposures in this industry are currently bordering on 1.5 rem/year. With closer supervision and strict adherence to radiation protection procedures, compliance with this guidance might be anticipated. Assuming that the combined impact of additional health physics personnel and instruction of field engineers would result in compliance, then the costs of the 1.5 rem/year limit would be roughly equivalent to the compliance costs of the industry's response to Range C.

9.3 SUMMARY OF COST OF COMPLIANCE

Compliance costs would result from the satisfying guidelines on Range C, Range B, and the alternative 1.5 rem/year limit. Three options were considered for compliance with the requirements of Range C, but only the costs of the medium and least-cost options were estimated. The medium-cost option would have full-time health physicists at each firm (but not at each field site) at an estimated annual cost of $20 million. The least-cost option substitutes consultants for full-time personnel to fulfill the supervisory role. The costs of this option are estimated to be $5 million. Staff time for training on the risks of exposure could add about $150,000 to total the annual cost.

All firms would be required to respond to Range B, but the costs of satisfying this requirement are subsumed under Range C. All major firms currently comply with Range B. If Range C were not promulgated, these firms would incur few costs, but the 300

other firms in the industry could incur $300,000 in annual cost. As for the alternative 1.5 rem/year whole-body limit, the industry is currently on the borderline of meeting this requirement. Assuming that the combined impact of additional health physics personnel and instruction of field engineers would result in compliance, then the cost of the 1.5 rem/year limits would be equal to the compliance costs of the industry's response to the Range C guidance.

CHAPTER 10

COST OF COMPLIANCE: NUCLEAR FUEL PROCESSING AND FABRICATION

10.1 INDUSTRY PROFILE: FUEL FABRICATION

This industry manufactures nuclear fuel for light water-cooled reactors (LWR's) and employs approximately 10,000 people. The raw material is uranium hexafluoride (UF_6), received in 2 MT containers from the uranium enrichment plants. The finished products are fuel assemblies ready to load into LWR's. Intermediate products consist of UO_2 powder, UO_2 pellets, and fuel rods (strings of pellets clad in zirconium alloy).

The industry is dominated by five large firms. A few small processors manufacture fuel for research reactors or high temperature gas-cooled reactors. In these cases, however, the finished products differ substantially from LWR fuel. Health physics considerations, however, are similar; i.e., the risks are from soluble and insoluble compounds of the uranium isotopes.

The process is similar in most of the major facilities. For some of the producers, the conversion to UO_2 and the processing of the UO_2 into fuel rods are performed at separate sites. Initially, UF_6 from the enrichment plant is converted to UO_2 powder by a chemical ammonium diuranate (ADU) process. The UO_2 powder is processed (e.g., hammermilling, predensification, granulating, blending) to prepare it for subsequent processing. Pressed UO_2 pellets are sintered, ground, and loaded into fuel rods. Fuel rods are assembled into fuel bundles, and the bundles are shipped to various reactor sites. A large number of support activities, such as laboratory analyses, process development, maintenance, and waste treatment are also conducted.

Health physics considerations, which are similar for the entire group, relate to the risks of internal exposure from soluble and insoluble compounds of uranium isotopes. No firm would have a problem in satisfying the proposed guidances on external exposure, assuming that the delegation of supervisory responsibilities from the current staff of radiation protection professionals to non-professionals is allowed. Therefore, the probable impact of the new regulations would result from the requirements on internal exposure and training in levels of risk, and additionally, in Range C, assuming that a strict interpretation of the supervisory requirements.

10.2 COST OF COMPLIANCE WITH GUIDANCE

The light water reactor (LWR) fuel fabrication industry is dominated by facilities operated by five of the largest manufacturing firms in the nation. The facilities range in age from 20 years to 5 years and the largest facility has five times the capacity of the smallest. The estimated impacts of revision to the guidance are several times larger than the impacts in any other industry except hospitals. However, great uncertainty as to the accuracy of these numbers exists and costs could be as much as an order of magnitude lower under some assumptions. Almost all of the compliance costs are a result of revisions in the limits for internal exposure, adjustment to the dose calculation models, and the summation of internal and external exposure. The case study report covers two facilities and discusses the compliance options anticipated by the two firms. In one, more precise estimation of internal exposure is expected to keep employees below the limits and in the other substantial engineering changes (extensive process containment construction) is expected to lower exposures. This study did not have sufficient resources dedicated to this industry to refine the industry estimates or to develop alternatives for regulation or compliance.

A survey sponsored by the Health Physics Society being conducted in the fall of 1982 is designed to provide cost estimates from each member of the industry which would then be published by the Atomic Industrial Forum (AIF). In addition, AIF is planning to sponsor an independent study of internal dosimetry in the fuel fabrication industry that may lead to a better understanding of compliance options. These studies may shed some additional light on the cost implications, but it is felt that additional study of internal exposure costs may be warranted. Such a study could result in a more thorough understanding of the impacts and/or program revisions that could substantially reduce these costs.

Guidance #1 - Annual Whole-body Limit - 5.0 rem/yr

Of approximately 4,000 monitored workers reported to the NRC in 1981,[1] none received an external exposure in excess of 3 rem. Thus, from the standpoint of external exposure, no impact from this provision is expected.

---

[1] *Op. Cit., NRC, NUREG-0714.*

Guidance #2 - Accumulated Lifetime Whole-body Exposure - 100 rem

This provision is not expected to be utilized. Therefore, no impact from this provision is expected as no long-time employees of the case study firm approached this limit.

Guidance #3 - Exposure to Extremities and Organs

Exposure histories at case study facilities indicate that high extremity exposures do not occur in this industry. Therefore, no impact from this provision is expected.

Guidance #4 - Anticipated Exposures in Range C (0.5 - 1.5 rem/yr)

Currently, exposures from the inhalation of uranium are "anticipated" in Range C, and it is possible to receive a "significant" contribution to Range C from a single task. It is expected that at least as high a percentage of workers would be in Range C under the new proposed Derived Air Concentrations for uranium (a factor of ten lower than the current maximum permissible concentration for insoluble uranium).

For the case study firms, technicians from the Radiation Safety Office monitor during incidents of high airborne concentrations of uranium. At least one individual, and at certain times during the week, two may be required to monitor.

If the "radiation safety professional" was permitted to delegate responsibility for supervision under this guideline, the costs are expected to be zero since this would fall within their current operating procedures. If not, and assuming similar Range C experience at the other plants, two additional health physicists would have to be hired at each of the five LWR fuel fabricators. The total annual costs would be $680,000.

Table 28: Cost Estimate for Range C Requirements for Fuel Fabrication
(Strict Monitoring Assumption)

Expense	No. of firms	Cost/ worker	Costs
Additional health physicists (2 per firm)	5	$68,000	$680,000

Guidance #5 - Anticipated Exposure in Range B (0.5 - 1.5 rem/yr)

The monitoring and supervision requirements are currently being carried out full-time by radiation protection professionals.

Guidance #6 - Training

With the exception of instruction in quantitative levels of risk, the training requirements in the proposed guidelines are currently being satisfied. To additionally satisfy the requirement relating to levels of risk, two additional hours of training for each of the industry's 4,000 workers are estimated. The average salary of a worker is $17,500. In addition, 60 more hours of instruction time (plus preparation) would be required at each firm, and there are five firms in the industry. The average salary of an instructor is $30,000. Therefore, assuming an overhead and fringe multiplier of 1.7 the annual costs for the industry are estimated to be about $127,500.

Table 29: Cost Estimate for Training Requirements for Fuel Fabrication

		No. of Person Hours	Cost/hr	Costs
1.	Staff time	8,000	$15	$120,000
2.	Instruction time	300	$25	7,500
	Total			$127,500

Guidance #8 - Internal Exposures

Case studies were conducted on two of the five firms in this industry. In one, the one-time cost of revision of internal monitoring was estimated by the case study firm to be $400,000, with annual costs of $100,000. In the other, a one-time cost of $9.8 million was estimated, with annual costs of $1.2 million. The first was a large fabrication facility, whereas the second was comparatively small and of older vintage.

It was initially felt that there would be no costs to one of the three large facilities in the industry because it is relatively new and has relatively low airborne levels of activity. Although it is true that airborne concentrations are relatively low at this newer facility, costs for internal compliance at this facility may be higher than those for other facilities. This is the case, in part, because this facility currently does not record MPC-hrs (levels are too low at the current limits, but will not be at the revised limits.) Imposition of the revised limits will require the initial development of an automated recordkeeping system, whereas these systems would only require upgrading at facilities where case studies were conducted.

Two of the four in this category are relatively large. The large case study firm is assumed to be representative of the large facilities. The case study firm would modify its procedures for measuring potential exposures to airborne concentrations of uranium from airborne monitoring data in conjunction with time and area assignments (TIA) for personnel. From the calculated potential exposures to airborne concentrations, internal doses are estimated by organ for each individual. These estimated internal doses are checked using the bioassay procedures, and measured external exposures obtained from personnel dosimetry are routinely added to the estimated internal doses.

The modification of this program entails (1) relaxing the conservative assumptions in the calculation of particle size, solubility and percentage of uranium enrichment, (2) more accurate monitoring of the time spent by each employee in each part of the plant, and (3) expanding the urinalysis and bioassay programs to cover all radiation workers with potential exposures in Range C. The staff responsible for the radiation protection at this facility at the time of the initial case study provided an estimate of expected costs by category. These costs were the best approximation by the staff of the actual cost including all fringe, overhead, and special hardware requirements. The approximate costs of these modifications were estimated to be $214,500 in initial costs and $28,000 in annual cost.

Table 30: Initial Cost Estimate for Large LWR Fuel Case Study Firm

		Initial Cost	Annual Cost
1.	TIA tracking system	$112,500	
2.	Adjustment of calculational procedures	$102,000	
3.	Whole-body bioassays-counting		$120,000
4.	Urinalysis		$ 8,000
	Total	$214,500	$128,000

Subsequent to the initial case study, the staff at the large facility left the firm and a new radiation staff was hired. In the course of an investigation of the cost of the revision to 10CFR Part 20 regulations, a follow up on the initial case study was conducted. The new staff agreed with the basic plan of the old staff for ensuring compliance, but felt the cost estimates were not realistic and that they failed to include all costs. The new staff provided a revised estimate of $400,000 in initial cost and $100,000 annual cost. The initial cost is comprised of various activities including new hardware for time-in-area assignments, equipment and measurements of solubility and particle size or better containment of process steps. No item-by-item breakdown was provided. The cost was estimated by the new staff by computing the total number of man-rem currently being accumulated annually in excess of the proposed limits and multiplying these by $1,000 per man-rem. The rationale is based on the proposed NRC safety goal for limitation on reactor hardware modification to $1,000 per man-rem reduced.

The second case study firm is representative of the two smaller firms in the industry, which are early vintage facilities. The small case study firm had one radiation worker for every four at a large facility. It is assumed that with production efficiencies, output of the small firm would be about one-fifth that of a large firm. The case study firm is considering two options to comply with the proposed guidance. The first is modification of its procedures to calculate airborne concentrations like the other case study firm. The costs of this approach estimated by the authors are believed to be more than proportional to the costs to the larger firm because much of the effort is comprised of planning, design and software. It is estimated, then, that the costs of modifying the firm's calculational procedures and augmenting its time-in-area (TIA) tracking system would be 75% of the costs to the larger firm. However, for an expanded urinalysis and bioassay program, the costs are estimated to be roughly proportional to output, and therefore, would be approximately 25% of the costs to the large case study firm. (A proportion of 25% instead of 20% is used in estimating this cost because the older firms are less efficient than the larger, more recent facilities.)

Table 31: Cost Estimate of Option 1 (modification of monitoring system) for Small LWR Fuel Case Study Firm

		Initial Cost	Annual Cost
1.	TIA tracking system	$100,000	
2.	Adjustment calculational procedures	$ 76,500	
3.	Bioassays		$30,000
4.	Urinalysis		$ 2,000
	Total	$176,500	$32,000

The second option for the small case study firm entails glove box containment in all operations. This option was initially supported for two reasons: first, the firm felt that modification of its calculational procedures would not sufficiently lower calculated internal exposures to satisfy the proposed requirement on Derived Air Concentrations (DAC's); second, the firm expressed anxiety about making adjustments which would not improve the protection of its workers, but serve only to satisfy new regulations. These cost estimates were developed by the engineering division of the case study firm. No further detail was provided, however, for the activities planned, these costs did not appear measurable.

The initial favorable response to glove box containment could change because the costs of this option might bankrupt the firm. The modification approach is fifty times less costly and it is believed it would satisfy the guidance.

Table 32: Cost Estimate of Option 2 (glove box containment) for Small LWR Fuel Case Study Firm

		Initial Cost	Annual Cost
1.	Containment	$2,400,000	
2.	Process modifications	$2,400,000	
3.	Ventilation	$3,100,000	
4.	Engineering and construction supervision	$1,900,000	
	plus annual operating costs		$1,200,000
	Total Costs	$9,800,000	$1,200,000

Several alternatives are available to estimate the total cost to this industry of the internal dosimetry guidance. Little information was available to this study to test the accuracy of the various cost options estimated by past and current staffs of the case study firms. In addition, it is difficult to separate the costs incurred simply because of a revised regulation and those related to better management control. It should also be noted that several benefits such as productivity or management information would accrue to manufacturers from those activities in addition to simple regulatory compliance. The cost of compliance with the guidance on internal exposures can be summarized below.

Table 33: Summary of Cost for LWR Fuel Industry

		Option 1		Option 2		Option 3	
		Initial (000)	Annual (000)	Initial (000)	Annual (000)	Initial (000)	Annual (000)
1.	2 Small Firms	209	32	19,600	2,400	390	50
2.	2 Large Firms	429	256	429	256	800	200
3.	1 Modern Firm	—	—	215	128	595	125
	Total	638	288	20,244	2,784	1,785	375

Option 1 is the low cost estimate based on the initial estimate of the large firm and assuming that 1) the costs for the other large firm are the same, 2) the procedures are applicable to the two smaller firms (at lower cost) and 3) the modern firm incurs no cost. Option 2 is the high cost option assuming that 1) the two large firms' costs are the same as for Option 1, 2) the two small firms undertake the high cost containment option and 3) the modern firm incurs costs equal to the large firms' cost. Finally, Option 3 assumes 1) the revised cost estimate provided by the large case study firm holds for both large firms, 2) adjustment of the two small firms' cost estimate under Option 1 to be consistent with the revised large firm estimate under Option 3 and 3) the modern firm costs are the average of the revised large and small firms' costs.

Only further study of the actual responses required by these firms could allow more accurate estimates. Substantial differences remain between the companies in their estimates of real costs of compliance. For the purpose of this study, the authors believe that the third option might be reasonable; further study is required however, before one estimate could be adequately defended against all others. The defender of Option 2 would be able to make a good case, but it is believed that these costs are so high that the smaller firms would leave the industry, which currently has substantial overcapacity.

Guidance #9 - Alternate Annual Whole-body Limit - 1.5 rem/yr

No impact from this provision is anticipated with regard to external exposures. At one case study facility, only 5 workers received exposures in excess of 1.5 rem in 1980 and similar exposure patterns were observed at the other facility. However, under the requirements for summation of internal and external exposures, facilities might be required to adopt a program similar to that described above for internal exposures. Thus, the cost of this program could be $2 million in initial costs and $400,000 in annual costs. If the revised internal program and a 1.5 rem annual limit were put in place at the same time, the above expenditures would cover both aspects of the guidance.

10.3 SUMMARY OF COST OF COMPLIANCE

Cost impacts for this industry are concentrated in Range C requirements for staff training and in monitoring of internal exposures. It is estimated that the industry would incur annual costs of $680,000 for Range C if non-professional health physics personnel are not permitted to assume supervisory responsibilities.

With the exception of instruction in levels of risk, the training requirements in the proposed guidelines are currently being satisfied. To additionally provide instruction in levels of risk to the industry's 4,000 potentially exposed workers would cost approximately $130,000 annually.

The control of internal expsoure is the highest potential cost area for this industry yet it is also the one for which the least is understood by either industry or the regulators. If the five firms that make up this industry respond by modifying the calculational procedures on airborne concentration, particle size, enrichment, solubility, and worker time-in-area, then the result in annual industry costs could be three or four hundred thousand dollars and initial costs of $1 to $2 million. However, if the two small firms opt for glove box containment as suggested by a case study, then the annual costs rise to $3 million, and initial costs could be $20.6 million. This alternative is believed to be less likely because it could put the smaller firms out of business.

Compliance with the alternative 1.5 rem/year limit would not be a problem for this industry with respect to external exposures. However, the summation of internal and external exposures could present compliance difficulties. This risk could be eliminated by a program similar to the internal exposure estimates described above.

CHAPTER 11

COST OF COMPLIANCE: COMMERCIAL POWER REACTORS

11.1 INDUSTRY PROFILE: COMMERCIAL POWER REACTORS

The technical specifications for a commercial nuclear power reactor requires the submittal of an annual report which provides the number of individuals exposed to radiation and their cumulative annual doses, broken down by type of personnel, work function, and occupation. These individual reports are compiled by the U.S. Nuclear Regulatory Commission (NRC) and reported to the public annually. Table 34, taken from an NRC report[1], is a summary of the annual information reported by commercial light water-cooled reactors and Table 35 is a summary of the annual whole-body doses at these reactors, broken down into exposure ranges, for the years 1969-1980.

In 1980, there were 68 operating light water-cooled power reactors with a total installed electrical generating capacity of 47,532 MWe (68 x 699 MWe). There were 80,331 individuals who received measurable exposures, out of a total number monitored of 133,878. These individuals had an annual collective dose of 53,796 man-rems. There were 311 individuals in 1980 with whole-body exposures greater than the proposed 5 rem/yr RPG. There were 12,786 individuals (assuming that one-half the individuals in the 1.0-2.0 rem/yr range received exposures in excess of 1.5 rem/yr) with whole-body exposures greater than the alternative RPG of 1.5 rem/yr.

It is expected that as of December 31, 1982, there will be 82 operating units at 54 sites, owned and operated by 44 utilities.[2]

---

[1] *Occupational Radiation Exposures at Commercial Nuclear Power Reactors 1979, Nuclear Regulatory Commission, March 1981, NUREG-0713.*

[2] *For those cases in which a plant is owned by more than one utility, only one utility is counted.*

Table 34: SUMMARY OF ANNUAL INFORMATION REPORTED BY COMMERCIAL LIGHT WATER COOLED REACTORS

1969 - 1980

Year	Number Of Reactors Included	Annual Collective Doses (Man-rems)	No. of Workers With Measurable Doses	Gross MW-Yrs Electric Generated	Average Dose Per Worker (Rems)	Average Collective Dose Per Reactor (Man-rems)	Average No. Personnel With Measurable Doses Per Reactor	Average Man-rems Per MW-Yr	Average MW-Yrs Generated Per Reactor	Average Rated Capacity (MWe) Net
1969	7 (5)	1,247 (663)	744*	1,289	0.89*	178	148*	1.0	184	247
1970	10 (7)	3,502 (1,609)	2,081*	1,092	0.80*	350	300*	1.9	109	300
1971	13 (9)	3,628 (1,981)	2,778*	3,220	0.71*	280	309*	1.1	248	367
1972	18 (12)	6,566 (4,213)	4,143*	5,802	1.02*	365	345*	1.2	311	408
1973	24	13,963	14,780	7,164	0.94	582	616	1.9	298	496
1974	34	13,722	18,466	10,883	0.74	404	543	1.3	320	575
1975	44	20,879	25,491	17,769	0.82	475	579	1.2	404	630
1976	53	26,433	35,447	21,911	0.75	499	669	1.2	413	663
1977	57	32,511	42,266	26,444	0.77	570	742	1.2	464	677
1978	64	31,809	45,998	31,614	0.69	497	719	1.0	494	702
1979	67	39,759	64,073	29,920	0.62	593	956	1.3	447	705
1980	68	53,796	80,331	29,155	0.67	791	1,181	1.8	429	699

*During the years 1969 through 1972, all plants reported collective doses but a few did not submit the number of personnel that received measurable doses. The number of reactors that did report doses and number of workers is given in parentheses in the second column. The collective doses shown in parentheses in the third column, as well as the asterisked numbers in the remaining columns, are all based on the data submitted by the number of reactors shown in parentheses. This correction, and others, changed some of the values from those appearing in earlier NUREG documents.

Source: Occupational Radiation Exposures at Commercial Nuclear Power Reactors 1979, Nuclear Regulatory Commission, March 1981, NUREG-0713.

Reproduced from best available copy.

Table 35: **SUMMARY DISTRIBUTION OF ANNUAL WHOLE BODY DOSES AT COMMERCIAL LIGHT WATER COOLED REACTORS**

1969 - 1980

Year	Number of Individuals with Whole Body Exposures in the Indicated Ranges (Rems)																Total Number Monitored	Annual Collective Doses (Man-rems)
	No Measurable Exposure	Measurable <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	6.0-7.0	7.0-8.0	8.0-9.0	9.0-10.0	10.0-11.0		
	0.0-1.25			1.25-2.0														
1969	2,479			128				134	65	25	5	2					2,838	
1970	6,839			146				166	163	88	98	8	1				7,509	
1971	8,586			410				315	137	105	17	11					9,581	
1972	14,095			688				532	199	111	46	21	9	6	6		15,713	
1973	19,043	5,494	1,698	1,214	740	652	2,468	1,584	422	251	125	71	38	16	7		33,823	13,963**
1974	20,472	6,735	2,887	2,058	1,182	908	2,503	1,378	471	226	86	30	6				38,938	13,722**
1975	18,854	8,841	3,674	2,750	1,685	1,339	3,948	1,872	691	423	169	60	24	12		1	44,343	20,879**
1976	25,704	12,821	5,130	4,135	2,520	2,030	4,880	2,354	789	487	188	70	26	11	5	1	60,521	26,433**
1977	24,888	13,970	8,534	5,050	3,258	2,486	6,162	2,837	1,130	589	141	66	36	21	6		67,134	32,511**
1978	30,142 l	18,639	6,943	5,504	3,399	2,498	6,405	2,989	1,080	418	67	26	8			(>12) 2	78,121 l	31,804**
1979	45,087	24,301	9,846	8,159	5,189	3,479	7,934	3,307	1,251	477	88	28	13	2		(11-12) 1	109,160	39,759**
1980	53,547	29,638	11,750	9,820	6,082	4,518	11,474	4,515	1,537	686	192	98	18	3			133,878	53,796**

*Summary of reports submitted in accordance with 10 CFR 20.407 by plants that had been in commercial operation for at least one full year as of December 31 of each of the indicated years.

**The collective doses were not reported by the plants but were calculated by the staff by using the method described in this document.

Source: See Table 34

11.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 - Annual Whole-Body Limit - 5.0 rem/yr and Guidance #9 - Alternate Annual Whole-Body Limit - 1.5 rem/yr

This section covers both the 5 and 1.5 rem whole-body limit. The methodology and procedures are the source for both estimates of cost, thus they are combined here for clarity. The management at most power reactors establishes administrative exposure limits which are below the regulatory limits. This procedure is used to provide adequate margins of safety in measuring, recording, and reporting actual exposures received by employees. One effect of reducing the regulatory limit is to narrow the margin of safety between the regulatory and the administrative limits, thereby increasing the probability of exceeding the regulatory limit. In our evaluation that follows, we adopt an administrative limit which is 80% of the regulatory limit.

Increased Worker Demand and Additional Collective Exposure

Stone and Webster Engineering Corporation used the data from the NRC annual report[1] to estimate the increase in the number of workers and the collective exposure resulting from a reduction in the whole-body annual limit. A correlation model was used, similiar in approach to that previously employed by Golden[2]. The Stone and Webster approach[3] is adopted along with the 1980 data from the NRC report (Tables 34 and 35), to estimate the additional number of workers and the additional collective exposure that would result from reductions in the regulatory limits. These increases result from an increase in the number of crew changes required to operate and maintain the power plants at reduced occupational exposure limits. To keep these plants operating, additional permanent station personnel and contract workers would be needed.

---

[1] *Occupational Exposure of Commercial Nuclear Power Reactors, 1980, Annual Report, U.S. NRC Report NUREG-0713, December 1981.*

[2] *J.C. Golden, "Effect of a Change in Regulatory Limits for Occupational Radiation Exposure on Manpower Requirements and Radiation Dose (Man-rem) Expenditures of a Nuclear Power Station", Commonwealth Company, June 1976.*

[3] *E.A. Warman et. al., "Estimated Additional Number of Workers and Additional Cumulative Exposure Due to Reducing Annual Dose Limits per Individual", Stone & Webster Engineering Corporation Report RP-29, April 1978.*

From the data base given in Table 35, and an administrative limit of 4.0 rem/year, the model estimated that 272 additional workers would be required, and collective exposure would increase 135 man-rem per year. For the regulatory limit of 1.5 rem/year, 25,677 additional workers would be necessary, and collective exposure would increase by 5,381 man-rem per year. The operation of the model is presented below.

Differential Operating Cost in 1982 Dollars

The Stone and Webster report did not address the differential operating costs. However, in assessing the impact on operating power plants of a 500 mrem/yr regulatory limit, Vance[1] developed a cost equation based on increased worker demand. His cost estimates have been converted to 1982 dollars by using an annual inflator of 11%. The methodology for developing the worker demand used in the Vance report adopted the same technique used by Pelletier[2] and Golden[3]. For the proposed 5 rem/year annual limit, it is likely that all of the additional workers required would be obtained by using contractor personnel. Therefore, using the Vance equation for the costs of contractor personnel (i.e., $1,270/outside worker), the cost of additional workers would be $342,735 in 1982 dollars.

For the alternative regulatory limit of 1.5 rem/year, the estimated increase required in workers is likely to be satisfied by a combination of a permanent station and contract personnel. We can make a reasonable estimate of numbers required in each category by using a ratio developed by Vance. From Table 35 in the Vance report, the ratio is 19 outside workers to one permanent station worker. Using this ratio, we obtain 1,284 permanent station workers and 24,393 outside contractor workers. The cost of hiring additional permanent station personnel is the worker's base salary multiplied by a payroll factor. Vance estimated that average annual salary for non-supervisory workers is $25,900 per year. Using an average direct payroll multiplier of 1.4, the total annual cost of a permanent employee $36,260. Therefore, the cost for contractor personnel would be $30.73 million, and for permanent station personnel, $46.56 million, for a total of approximately $77.4 million in 1982 dollars.

---

[1] *J. Vance et. al., "A Preliminary Assessment of the Potential Impacts of Operating Nuclear Powerplants of a 500 Mrem/Year Occupational Exposure Limit", prepared for the Atomic Industrial Forum, April 1978.*

[2] *C.A. Pelletier and P.G. Voilleque, "Potential Benefits of Reducing Occupational Radiation Exposure", Atomic Industrial Forum Report AIF-NESP-010R, May 1979.*

[3] *Op. cit., J.C. Golden, June 1979.*

To estimate the costs of outage extension and additional facilities under the reduced regulatory limits, we used the most recent assessment of reduced occupational exposure limits conducted by Catalytic, Inc. for the Atomic Industrial Forum. Extension in the outage time results from the extension in critical path duration, which is a consequence of the increased number of workers required for a task. The cost associated with the outage extension is estimated from the cost of replacement power, assumed to be $22,700 (net) per hour. These additional workers require additional on-site facilities for training, supplies, and offices.

Under the assumption that the proposed EPA limit would be delivered during a calendar quarter (which was the time frame used in the Catalytic report), the proposed 5.0 rem/year annual limit was estimated to have no impact. For the proposed alternative annual limit of 1.5 rem/year (using the 1.0 rem/quarter regulatory limit), the Catalytic report estimates a cost of $106.06 million for outage extension and $3.2 million for additional facilities in 1982 dollars.

Table 36 presents the total estimated costs, in 1982 dollars, of the proposed EPA annual limit and the alternative annual limit for the entire commercial reactor industry in the year 1980.

Table 36: Total Estimated Costs for All Operating Nuclear Power Plants of Reducing Regulatory Limits

Impact	Regulatory Limit	
	1.5 rem/yr	5.0 rem/yr
Differential Worker Demand		
Permanent Station	1,284	0
Outside Workers	24,393	272
Total	25,677	272
	1.5 rem/yr (million)	5.0 rem/yr (million)
Differential Operating Costs (1982 dollars)		
Personnel (Perm. Stat.)	$ 46.56	—
Personnel (Outside)	30.73	0.34
Outage Extension	106.06	0.0
Additional Facilities	3.22	0.0
Total Additional Cost	$ 186.65	0.34

The Catalytic report was also used to check our earlier cost estimates using the Stone and Webster methodology.[1] It is believed that this was the most valuable application of the Catalytic report because it considered reductions in quarterly limits, rather than annual limits, and therefore was not appropriate as a principal estimator of the costs of the proposed EPA annual limits.

The comparison of the results the Catalytic report with the costs estimates from the Stone and Webster methodology was accomplished by assuming that the entire annual limit would be delivered during a calendar quarter. This can be justified on the basis that most of the exposure is obtained during the annual refueling and maintenance outage, which is less than three months in duration.

On this basis, the proposed 5.0 rem/year annual limit would obviously have no impact (it is higher than the current quarterly limit). For the alternative annual limit of 1.5 rem/year, the data is compared with the Catalytic result corresponding to a quarterly dose limit of 1.0 rem/qtr., which is $2.2 million per 1,100 MWe reference plant in 1982 dollars. Multiplying by the 43 reference plants required to obtain the total 1980 generating capacity given in Table 34, an additional manpower cost of roughly $93.67 million in 1982 dollars is obtained. This is considered to be in relatively close agreement with our estimate (using the Stone and Webster methodology) of approximately $77.36 million.

Calculation of Cost of Compliance

The terms used in the Stone and Webster model are defined as follows:

D_D = designated individual dose (rem/year)

D_L = regulatory limit (rem/year)

D_A = administrative limit set by licensee to assure regulatory limits are not exceeded

M_D = number of workers receiving an annual dose greater than D_D in the original data base

---

[1] *Study of the Effects of Reduced Occupational Radiation Exposure Limits on the Nuclear Power Industry, prepared by Catalytic, Inc., Atomic Industrial Forum Report AIF-NESP-017, January 1980.*

ΔM_D = additional number of workers required if D_D is also equal to D_A

R_D = collective exposure accumulated by M_D workers receiving annual doses above D_D in the original data base

ΔR_D = additional collective exposure accumulated if D_D is set equal to D_A (in man-rem)

E_o = individual worker nonproductive fraction of his total dose in the radiation environment in the original data base (fraction is defined as nonproductive dose divided by nonproductive plus productive dose). For this application, E_o is assumed to be equal to 0.1.

The principal assumptions made in the Stone and Webster correlation model are:

- The administrative limit is set as $D_D = D_A = 0.8\ D_L$ (e.g., for a regulatory limit of 5 rem/year, $D_D = D_A = 0.8 \times 5.0 = 4.0$ rem/year).
- The nonproductive dose per worker remains constant.
- The total nonproductivity fraction, designated as E, increases linearly with the number of workers. This follows as a consequence of the presumption that the total productive dose remains constant. Mathematically, this is expressed as $E = E_o (M_D + \Delta M_D)/M_D$.
- The total man-rem previously above D_A is shared by the increased number of workers, $M_D + \Delta M_D$, with each of the individual workers presumed to receive the administrative limit D_A.

The mathematical model based on the above assumptions and definition of terms is simply stated as follows:

Additional Worker Demand (ΔM_D)

$$\Delta M_D = \frac{(1 - E_o)R_D}{D_A - \frac{E_O R_D}{M_D}} - M_D$$

Additional Collective Exposure (ΔR_D)

$$\Delta R_D = D_A(M_D + \Delta M_D) - R_D$$

From the data base given in Table 35, and an administrative limit of $D_A = 4.0$ rem/year, it is determined that $M_D = 997$ workers and $R_D = 4941$ man-rem. R_D was calculated by multiplying the number of individuals in each dose range by the midpoint of each range and then summing the product. This method was used in Stone and Webster to calculate the collective dose. Our estimate is as follows:

Additional Worker Demand (ΔM_D) for $D_L = 5.0$ Rem/year

$$\Delta M_D = \frac{(1 - 0.1)(4941)}{4.0 - \frac{(0.1)(4941)}{997}} - 997 = 272 \text{ additional workers}$$

Additional Collective Exposure (ΔR_D) for $D_L = 5.0$ Rem/year

$$\Delta R_D = (4.0)(997 + 272) - 4941 = 135 \text{ additional man-rem}$$

Therefore, using the Vance[4] equation for the costs of contractor personnel, we obtain:

$$\$_0 = \$1{,}270\,(\Delta M_D)$$

$$= (\$1{,}270)(272 \text{ workers}) = \$342{,}735 \text{ in 1982 dollars for } D_L = 5.0 \text{ Rem/year.}$$

Consider the alternative regulatory limit of $D_L = 1.5$ rem/yr., it is determined from Table 35 that $D_A = (0.8)(1.5) = 1.2$ rem/year, M_D[1] = 18,523 workers and $R_D = 38{,}819$ man-rem.

Using these data, our estimate is as follows:

---

[1] Simplify by using a value for $D_A = 1.0$ rem/year

Additional Worker Demand (ΔM_D) for D_L = 1.5 Rem/year

$$\Delta M_D = \frac{(1 - 0.1)(38,819)}{1.0 - \frac{(0.1)(38,819)}{18,523}} - 18,523 = 25,677 \text{ additional workers}$$

Additional Collective Dose (ΔR_D) for D_L = 1.5 Rem/year

$$\Delta R_D = (1.0)(18,523 + 25,677) - 38,819 = 5,381 \text{ additional man-rem}$$

For the alternative regulatory limit of 1.5 rem/year, the estimated increase required in workers is likely to be satisfied by a combination of a permanent station and contract personnel. A reasonable estimate can be made of numbers required in each category by using a ratio developed by Vance. From Table 2 in the Vance report, the ratio is 19 outside workers to one permanent station worker. Using this ratio, we obtain 1,284 permanent station workers and 24,393 outside contractor workers. The cost of hiring additional permanent station personnel is the worker's base salary multiplied by a payroll factor. Vance estimated that the average annual salary for nonsupervisory workers is \$25,900 per year in 19. Using an average direct payroll multiplier of 1.4, the total annual cost of permanent employee in 1982 is \$36,260/year. Therefore, we obtain:

$$\begin{aligned} \Delta \$_0 &= (\$1,270)(24,393) \\ &= (\$30.75 \text{ million for contractor personnel} \end{aligned}$$

and

$$\begin{aligned} \Delta \$_0 &= (\$36,260)(1,284) \\ &= \$46.56 \text{ million for permanent station personnel,} \end{aligned}$$

for a total of approximately \$77.36 million in 1982 dollars for D_L = 1.5 Rem/year.

The Catalytic report was also used to check our earlier cost estimates using the Stone and Webster methodology. It is believed that this was the most valuable application of the Catalytic report because it considered reductions in quarterly limits, rather than annual limits, and therefore was not appropriate as a principal estimator of the costs of the proposed EPA annual limits.

The comparison of the results the Catalytic report with the costs estimates from the Stone and Webster methodology was accomplished by assuming that the entire annual limit would be delivered during a calendar quarter. This can be justified on the basis that most of the exposure is obtained during the annual refueling and maintenance outage, which is less than three months in duration.

On this basis, the proposed 5.0 rem/year annual limit would obviously have no impact (it is higher than the current quarterly limit). For the alternative RPG of 1.5 rem/year, the result compares with the Catalytic result corresponding to a quarterly dose limit of 1.0 rem/qtr., which is $2.2 million per 1,100 MWe reference plant in 1982 dollars. Multiplying by the 43 reference plants required to obtain the total 1980 generating capacity given in Table 33, we obtain an additional manpower cost of roughly $93.67 million 1982 dollars. This is considered to be in relatively close agreement with our estimate (using the Stone and Webster methodology) of approximately $77.36 million.

Guidance #2 - Accumulated Lifetime Exposure - 100 rem

This industry is one of the only ones included in this study that had consistently strong objections to the 100 rem lifetime limit. Aside from the claims that this guidance was not based on a sound technical rationale, power plants felt that several key personnel who carry out technical operations in high radiation fields (i.e., steam generator jumper) would reach the lifetime limit during their career. These individuals would be extremely difficult to replace. One estimate provided by a case study firm was that 150 such key contractor employees would be effected. If we assume that an additional 75 such workers would allow lower utilization of these key individuals, the cost to the industry would be the fees paid by reactors to cover the cost of these additional workers. Assuming full cost per worker of $100,000 per year, this guidance would result in an annual cost of $7,500,000. Serious concern was raised by all case study reactors as to whether any additional skilled workers could be made available, at any reasonable price.

Guidance #3 - Exposure to Extremities and Organs

For the case study plants, maximum annual extremity exposures appear to average a few rem per year for a few workers. The maximum all time extremity exposure for the case study plants was less than 20 percent of the proposed limit. Therefore, it is unlikely that the revised extremity limits would have an impact. Extremity exposures are monitored if fields exceed specified thresholds. Because of this historical monitoring and because the results have not indicated extremity exposures approaching the limits, it is assumed that a pilot program to demonstrate that extremity exposures are well below the limit would not be required.

When high beta doses to the eye are anticipated, protection goggles are worn and this does not degrade personnel performance. Since this is generally the only potential for eye lens expsoure, significantly different from whole-body exposures, it is not anticipated new costs will be incurred.

Guidance #4 - Anticipated Exposures in Range C (1.5 to 5 rem/yr)

All power reactors would anticipate exposures in excess of 1.5 rem for some percentage of workers. The actual number would depend on the number and length of station outages during the year. Only one of the five reactor stations visited currently complies with the requirements for monitoring Range C staff and those procedures appear extremely atypical. Three stations indicated that supervision by HP technicians are provided when radioactive fields are anticipated to be 1 rem/hr. To comply with Range C requirements, it was generally agreed by the staff of each station that such monitoring would be required in all fields of 100 mrem/hr. and that such monitoring would require an appropriate doubling of the HP technician staff at each reactor. This includes both permanent station personnel and contractor personnel brought in during outages.

It is assumed that compliance with Range C would require an increase of 100 percent of the HP technicians at a full cost of about $45,000 per employee ($26,000 salary plus 50 percent fringe and overhead plus 25 percent overtime earnings). The current staff of HP technicians at the 54 sites with operating units is about 5,400[1]. Therefore the total cost would be $243 million dollars. By comparison, the estimated cost for the alternate whole-body limit of 1.5 rem per year was estimated to be about $200 million. The latter estimate is obtained utilizing current HP practices and additional workers to distribute high doses.

---

[1] *Op. Cit., NRC, NUREG-0713.*

It should be noted that both strategies rely heavily on the industry being able to attract a substantial number of new workers. Such activity would no doubt increase unit cost of workers and could increase the estimates by 15 to 20 percent.

Guidance #5 - Anticipated Exposures in Range B (0.5 - 1.5 rem/yr)

All nuclear power reactors have employees exposed in Range B and currently carry out all activities required by the guidance. Therefore, there will be no cost impact.

Guidance #6 - Training

No impact from this guidance is anticipated as all stations currently have extensive training programs that meet or exceed the requirements of the guidance.

Guidance #7 - Exposure to the Unborn

The females at the case study reactors accounted for 2 to 15 percent of the radiation workforce. Most of the utilities are already operating under Alternative a for the protection of the embryo/fetus. Some of them go so far as to remove pregnant females from work in radiation areas. For one of the case study utilities, the pregnancy policy is in a state of flux, and an option is to specify in job descriptions a willingness to be exposed in excess of 0.5 rem over nine months. Females who accept the job under these conditions, therefore, would be subject to dismissal should they become pregnant.

The cost impact on the utilities of Alternative b or c would be negligible. There would, however, be an increasing disinclination to hire females of child bearing age for work in radiation areas. To a certain extent, this disinclination has been present over recent years at a number of plants.

Guidance # 7 - Internal Exposures

It is not expected that the revised internal exposure provisions would alter the existing internal monitoring programs at the plants. Those utilities (the majority) that use MPC- hours as the surrogate for internal dose will continue to do so, and the calculated doses are so low that it is unlikely that any utility will refine their methods by measuring particle size, solubility fraction, etc. The few utilities that use the results of bioassay for compliance will probably not alter their procedures. Amongst the case study plants, there are no instances of intake in recent memory that exceed 30 percent of the limits. Nonetheless, it is highly unlikely that any utility will discontinue its existing monitoring program.

The revised provisions for handling internal exposures will require modifications in dose accounting software. The requirement to convert the internal monitoring data to internal organ dose and combine with external exposure applies for all monitored workers. Also, it is assumed that the conversion factors or algorithms will be supplied by the NRC in the form of Regulatory Guides (and be internalized as a cost to the NRC).

A considerable range of one-time costs for these software modifications were estimated by the case study utilities. Two utilities estimated no costs, one estimated $10,000, another $130,000, and yet another 2½ man-years (not including the costs of reformatting the output records or retraining.) The average is approximately $50,000 (assuming $50,000 for a man-year). This is considered realistic, since the $130,000 estimate would most likely include some reformatting of records. At $50,000 for each of 44 utilities, the total initial cost of these modifications would be $2.2 million.

11.3 SUMMARY OF COST OF COMPLIANCE

Cost of compliance with the proposed guidelines are significant for this industry. Major cost impacts occur in the whole-body limit, lifetime limit, Range C and internal exposures guidances.

The 5.0 rem/year limit could result in the need for about 300 additional outside workers at an annual cost of $350,000. For the alternative 1.5 rem/year limit, about 1,300 permanent station workers and 24,000 outside workers would be required. In addition, there would be costs relating to outage extension and additional facilities. The combined annual costs of additional operating expenses and personnel are estimated to be $200 million. Initial expenses for additional facilities are estimated to be $3 million.

Other costs would include $7.5 million for addition of several specially skilled workers for work in high radiation fields. Additional workers would reduce the likelihood of any workers exceeding the lifetime limits. Compliance with Range C would require a substantial staff increase in health physics technicians. It is estimated that the current staff of HP technicians at the 54 operating sites would have to be doubled to provide monitoring required by Range C. The cost to the utilities of these staff is estimated to be about $250 million. On the other hand, these costs would be greater than the cost for operating within the 1.5 rem/year limit, that is $200 million annually and $3 million initial expenditures. An additional $2 million in one-time programming and software modifications for internal monitoring would be expected. Thus it is expected that utilities would choose to operate below the 1.5 rem/year limit, thus eliminating Range C monitoring requirements.

CHAPTER 12

COST OF COMPLIANCE: UNIVERSITY REACTOR

12.1 INDUSTRY PROFILE: UNIVERSITY REACTORS

There are 50 university reactors currently operating in the U.S.[1] The larger reactors are generally 2 MW(t) swimming pool reactors with MTR-type fuel of which about 10 are currently operating. These reactors are licensed by NRC for experimental purposes and are not designed to produce electric power. They generally are used by student and faculty to evaluate experiments designed to study radiation effects and to produce radionuclides for research. Typical experiments would include neutron activation analyses, analysis of radioactive partition coefficients in water/oil systems, gamma-ray spectroscopy and neutron embrittlement of reactor pressure vessel steels.

Only one case study was undertaken in this sector and the findings are extended to cover all reactors. The case study reactor was a large research reactor.

12.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 - Annual Whole-body Limit - 5 rem/yr.

NRC data reports no exposure in excess of 4 rem in 1979[2] and only 1 in excess of 3 rem in that year. Therefore, no impact from the guidance is anticipated.

Guidance #2 - Accumulated Lifetime Exposure - 100 rem

The highest lifetime exposure recorded by the case study reactor was less than 10 rem. In general, there are no activities at these facilities that would place workers or students in danger of reaching that limit. Therefore, there would be no impact.

---

[1] *Nuclear Reactors Built, Being Built or Planned in the U.S. as of December 31, 1981; U.S. Department of Energy, Report DOE/TIC-8200-R45, June 1982.*

[2] *Op. cit., NRC, NUREC-0714.*

Guidance #3 - Exposure to Extremities and Organs

The experience of the case study institution was that no excessive extremity exposures occur in normal research reactor activities. Measured hand exposures are only ten percent of the proposed limit, and eye exposures are expected to be minimal, although they are not currently monitored. Therefore no impact from this provision is expected.

Guidance #4 - Anticipated Exposure in Range C (1.5-5 rem/yr.)

Exposures in excess of 1.5 rem/yr. are not anticipated at these types of facilities. This is corroborated by recent experience at the case study reactor in which the highest annual exposures were in the range of 0.5 to 0.75 rem. Nevertheless, the case study facility abides by the proposed Range C supervision and monitoring guidance. A health physicist is permanently assigned to the reactor facility. Any time that something is taken out of the pool, the health physicist supervises the activity and performs continuous monitoring. These procedures are believed to be typical of university reactors.

NRC data for 1979 indicate that about one percent of monitored personnel in the research reactor category, (includes university reactors, and privately owned research reactors) received exposure in excess of one rem and most of this case probably below 1.5 rem. It is believed that if there are some exposures over 1.5 rem at university reactors, they are few and could be lowered at little or no cost.

Guidance #5 - Anticipated Exposures in Range B (.5 - 1.5 rem/yr.)

University reactor facilities conform to the proposed guidance of Range B based on data from the case study facility. Every proposed experiment is reviewed by the Reactor Safety Committee. Moreover, as discussed above, facilities are often monitored in conformance with the Range C guidance.

Guidance #6 - Training

In general it is believed that all University reactor personnel receive adequate training. To the extent that quantitative measures of risk are not presented, they could be added to the curriculum at little or no cost.

Guidance #7 - Exposure to the Unborn

The case study facility is currently operating under a mandatory version of Alternative a. It would not be difficult to amend the existing policy to conform with Alternative b. This would state that a female of child-bearing age could voluntarily decide not to pull samples out of the pool. This is the only activity that could potentially expose the fetus in excess of 0.2 rem/mo. It would not be difficult to accommodate this degree of flexibility, since only about 20 percent of operators are female.

If Alternative c were imposed, women of child-bearing age could not be hired as reactor operators. This should not be an extreme hardship for the facility since sufficient number of male operators are usually available. However, it would limit the potential sources of support for females.

Some concern was expressed about the ability to estimate the committed dose equivalent to the fetus from radionuclides taken into the body. It is assumed that the NRC would provide some guidance, possibly as a Regulatory Guide, on the calculation of internal exposure to the fetus. In any case, it is unlikely that internal exposures would contribute significantly to fetal exposures at this facility. It is believed that there would be no cost impact from this guidance.

Guidance #8 - Internal Exposure

There would be no impact at the case study facility, since no additional monitoring would be required under normal operations. At present, routine bioassays are performed at the reactor facility.

The Derived Air Concentrations (DAC's) for the radionuclides potentially encountered at the reactor facility, primarily gamma and beta emitters, are largely unchanged under the EPA guidelines. The levels of tritium in the air above the pool are well below the detection limit (8×10^{-7} μCi/ml).

No new software or staff would be required at the case study facility for treatment of internal exposures. Measurable intakes are infrequent and several well-qualified staff and faculty members would be available to estimate the dose. Assuming this facility is representative, no impact from this guidance is expected.

Guidance #9 - Alternative Annual Whole-body Limit

A 1.5 rem/yr. limit would have no impact at the case study facility. Limits are currently maintained nearly an order of magnitude below the proposed 5 rem annual limit. At present, the Radiation Safety Committee must approve exposures in excess of 0.5 rem/yr. Only a couple of individuals have been exposed in excess of 0.5 rem/yr. over the past two years at this facility, and their exposures have been less than 0.75 rem/yr. No activities at university reactors should require exposure above 1.5 rem per year. Therefore no cost impact is anticipated.

12.3 SUMMARY OF COST OF COMPLIANCE

Little or no cost for compliance with the proposed guidance are anticipated.

CHAPTER 13

COST OF COMPLIANCE: NUCLEAR PHARMACY

13.1 INDUSTRY PROFILE: NUCLEAR PHARMACIES

Nuclear pharmacies constitute a new industry that supplies nuclear medicine to hospitals. Currently about half of all nuclear medicine is prepared by independent pharmacies that did not exist 15 years ago. The independent pharmacy purchases pharmaceutical remedies from small sources manufacturers (see Chapter 7) and prepares unit doses that are delivered to hospitals ready for use with individual patients. Due to recent consolidation this $60 million dollar industry is now dominated by two firms who share the market equally. Both firms are aggressively marketing their services in an attempt to expand beyond the major metropolitan areas where large markets attracted the initial pharmacies. It is estimated that there are currently about 60 pharmacies with about 1,000 employees. Corporate plans for the dominate firms call for opening about one additional pharmacy per month over the next several years.

Products and Services

Ninety percent of the radiopharmaceuticals consist of Tc-99m (eluted from a molybdenum generator) or Tc-99m — tagged compounds. Most of the remainder are either iodine-131 or xenon-133. A smattering of Tl-201, Ga-67, I-123, Yb-169, Cr-151, and In-111 is also handled. A typical pharmacy handles approximately five Curies per day of Tc-99m and roughly 200 mCi of the others. Operations of both major firms are very similar. A case study was conducted for one firm and the other was contacted by phone.

13.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 - Annual Whole-body Limit - 5.0 rem/yr.

Whole-body exposures for this industry are extremely low. The case study firm did not have an exposure in excess of 1 rem in 1981. Therefore, no impact from this provision is expected.

Guidance #2 - Accumulated Lifetime Exposure - 100 rem

Data from the case study firm and other sources indicate that currently no lifetime exposures exceed 5 rem. Operation of these independent pharmacies should result in exposure histories similar to or below in-hospital pharmacies where the data also supports the assumption that no employees will approach the 100 rem lifetime limit. Therefore, no cost impact is attributed to this guidance.

Guidance #3 - Exposure to Extremities and Organs

Some efforts are required to assure that hand exposures are maintained below 50 rem/yr. Continuing the relatively aggressive radiation protection programs instituted by the two principal firms in this industry should be sufficient to control hand exposures. The incremental costs to keep hand exposures under the revised limit should be minimal.

There may actually be a cost benefit from the new extremity limits. Presently, in the case study firm, the cost of personnel monitoring is $36,000/yr. Approximately $9,000 of this is from the weekly hand monitoring of 100 employees ($1.72/badge/week). If the quarterly limit were dropped, monthly monitoring should suffice, providing a cost savings of approximately $7,000. Also, the annual costs for analysis of exposure data is estimated to be approximately $15,000. This would be reduced by approximately 50 percent if weekly monitoring were dropped. Procedures are similar for both firms and thus these benefits would be assumed to accrue equally to both.

Guidance #4 - Anticipated Exposures in Range C (1.5 to 5 rem/yr)

Exposures in excess of 0.3 times an RPG are only possibly anticipated for the hands (greater than 15 rem/yr.). At present, the average annual exposure to the hands in the case study firm is 12 rem/yr. High doses to the hands are obtained by the dispensers who "pull doses." However, full-time supervision and monitoring by a radiation protection professional would not be required under the proposed guidelines because there is no single task in which the contribution to the annual exposure is "significant." These are repetitive tasks that accumulate dose in a uniform way over the entire year.

Guidance #5 - Anticipated Exposure in Range B (0.5 - 1.5 rem)

The guidance for exposures in the range of 0.1 to 0.3 RPG describes the existing program at both firms. Thus, there would be no impact from this guidance.

Guidance #6 - Training

The training program which is currently under development by the case study firm satisfies the proposed guidance. By the time that the guidelines are formally proposed, this training program will be well under way and it is believed a similar program will also be in place for the other firm. Thus, no impact.

Guidance # 7 - Exposure to the Unborn

Approximately five percent of the dispensers and handlers of the case study firm are female. All female employees are required to read NRC Regulatory Guide 8.13. The case study firm suggested that if a female becomes pregnant, she would probably be asked to take a leave of absence. Exposures to the fetus could probably not be maintained below 500 mrem with certainty. If a handler were to become pregnant, she would be kept out of the restricted area (no packing, just delivering). Whole-body exposures to deliverers can easily be kept below 500 mrem over a nine-month period. Therefore, the case study firm is currently operating under a mandatory version of Alternative a, and it is believed that the other firm has a similar program.

It is possible, though unlikely, for a worker who milks generators or compounds radiopharmaceuticals to receive a W.B. exposure in excess of 0.2 rem/mo. Thus, if Alternative b or c were to be promulgated, women of child-bearing ages would be precluded from doing these jobs. However, there are currently only about six women in the case study firm who perform these jobs. Thus, the cost impact would be inconsequential. However, these alternatives would pose substantial EEO problems.

Guidance # 8 - Internal Exposure

The two radioisotopes of concern from an internal exposure perspective are iodine-131 and xenon-133. Intakes of these isotopes are currently a very small fraction of the proposed RIF's.

If the proposed internal exposure guidance were to be promulgated, no additional monitoring is expected to be required. However, the existing software would have to be modified to convert the measurements to dose and to add the weighted organ dose to the external exposure. It is estimated that the industry cost to develop the additional software is approximately $30,000. Moreover, the operating costs for the dose tracking systems, currently at approximately $30,000/yr. for the case study firm, would be increased by an estimated 30 percent, or approximately $18,000 annually for the industry.

Guidance #9 - Alternative Annual Whole-body Limit - 1.5 rem/yr.

The industry could operate within a 1.5 rem/yr. W.B. exposure limit with little or no impact.

13.3 SUMMARY OF COST OF COMPLIANCE

This industry which has developed over the past decade is dominated by two firms. The cost of compliance is estimated to be entirely concentrated in activities associated with the upgrading of software to account for the changes in the internal exposure guidance. Costs are expected to be about $20,000 per year.

CHAPTER 14

COST OF COMPLIANCE: URANIUM MILL

14.1 INDUSTRY PROFILE: URANIUM MILL

As of January 1, 1982, 18 firms were operating 20 uranium mills with total employment of approximately 2,400 workers.[1] Industry output continues to contract in 1982 after a decade of steady increase to a 1980 peak of 16,745 thousand tons of ore received. The uncertain future of nuclear power and the current uranium surplus leaves the future of this industry difficult to predict. For the purpose of this cost study we have assumed that the 20 operating plants will continue to operate for the foreseeable future. Further contraction of the industry would reduce the estimated costs roughly in proportion to lost capacity.

The industry currently consists of 20 operating uranium mills, located in western states and accounts for 85% - 90% of natural U_3O_8 production. These mills have a combined rated capacity of about 54,000 tons of ore per day and an output of 21,000 tons per year of yellowcake. Of these mills, 76 percent utilize conventional acid leach - solvent extraction processes, and 10 percent utilize conventional alkaline leach processes.

Although record yellowcake production occurred during 1980, reports for 1981 indicate a decline in production. For calendar year 1982, a greater decrease in production is expected. During 1981, several of the larger mills curtailed their operations, while others either shut down completely or temporarily closed down until such time as demand for yellowcake catches up with supply. It is estimated that the workforce in the industry has been reduced by about 60 percent because of this decreased demand.

14.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 - Annual Whole-body Limit - 5 rem/yr

No impact from this provision is expected with respect to external exposure. In 1979, no exposures reported to NRC[2] were in excess of 4 rem and only 4 of 1,500 monitored workers had doses reported over 2 rem.

---

[1] *Statistical Data of the Uranium Industry, U.S. Department of Energy, GSO-100(82), January 1982.*

[2] *Op. cit., NRC, NUREG-0714.*

Guidance #2 - Accumulated Lifetime Limit - 100 rem

The case study firm indicated that this provision would have no impact, as no mill employees would approach this limit. Some concern was expressed for mine, however, this would not affect the mill unless mine workers shifted to the mill. Thus no impact from this provision is expected.

Guidance #3 - Exposure to Extremities and Organs

Potential exists for high hand and skin exposure for scrap pickers who sift the ore as it arrives at the mill, where a dose rate of 3 mrem/hr is expected. However, it is expected, from the experience of the case study mill, that these exposures would be less than ten percent of the new limit. Therefore, no impact from this provision is expected.

Guidance #4 - Anticipated Exposures in Range C (1.5 to 5 rem/yr)

The average annual internal exposure in the precipitation and packaging area of the case study mill is 1.62 rem. All other areas are less than 1.5 rem. About three percent of case study employees monitored receive whole body exposures in excess of 1.5 rem. The main impact from the proposed guideline would be due to the new internal exposure limit. The solubility class for the Derived Air Concentrations for uranium inhalation is a critical parameter for compliance in this industry. If the new guidelines on internal exposures are imposed it would be difficult to maintain combined exposures significantly below the limit. The difficulty in meeting the new internal limit is discussed later in this chapter.

Potential internal exposures are monitored with a multiple air sampling system and external exposures for all personnel are measured with TLD dosimeters. One senior environmental engineer, one environmental technician and two industrial hygiene and health physics technicians provide radiation protection services. It is anticipated that a certified health physicist at a cost of $40,000 per year plus a 35 percent overhead burden would have to be employed in the precipitation and packaging area to comply with the proposed Range C guidance. Assuming each of the 20 mills would have to hire 1.5 health physicists, the industry cost would be $1.1 million annually.

Guidance #5 - Anticipated Exposures in Range B (0.5 - 1.5 rem)

The case study mill is currently operating in full compliance with this proposed guideline. All personnel wear TLD dosimeters to measure external exposures. Potential internal exposures are monitored with a multiple air sampling system. One senior environmental engineer and two industrial hygiene and health physics technicians maintain records on external sources of radiation and airborne concentrations at the four mill operating areas, review health physics procedures and are available to monitor during non-routine operations. It is assumed that other industry participants have a similar structure and that no costs will result from this guidance.

Guidance #6 - Training

There would be no impact from the training requirements of the proposed guidelines, since it is assumed that all new employees in the industry receive instruction in radiation protection principles, as a result of the NRC or NRC Agreement State license.

Guidance #7 - Exposure to the Unborn

Approximately eight percent of the personnel at the case study mill were females of child-bearing age. However, there would be no impact from the proposed provision for the embryo/fetus, since the present corporate policy follows NRC Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure." Women are instructed to inform their supervisors when they are diagnosed to be pregnant. As soon as the supervisor is notified, the woman is removed from a high exposure job and is assigned to a job in a non-controlled area. It is assumed that other mills currently follow Regulation Guide 8.13 and therefore, there would be no impact from proposal a. Alternatives b and c would result in females being denied positions. It is not anticipated that this would result in any labor supply difficulty.

Guidance #8 - Internal Exposures

Data from the case study mill indicates that the current average intakes in most areas are higher than the Allowable Limit of Intake (ALI) prescribed by ICRP-30 for insoluble (Class Y) uranium — 0.054 uCi.[1] Therefore, in order to comply with the new standards, the conservative assumption of total insolubility utilized by the case study mill and assumed to be utilized by other mills would have to be relaxed. The DAC for soluble uranium (Class D) is a factor of about 30 higher than that for insoluble uranium (Class Y). It is estimated that using actual solubility fractions would lower the calculated exposure by a factor of about 15. The justification for this relaxation would require continual determination of the actual solubility fractions in the mill process areas.

Establishment of a routine system for measuring solubility fractions would take a professional approximately six person-months of effort. Then routine monitoring of this parameter is expected to take a technician approximately ten person-days each month. (It is assumed that NRC would require continual routine monitoring of this parameter.) The one time equipment cost for solubility fraction sampling is estimated by the case study mill to be approximately $22,000. Additionally, laboratory support is estimated to cost approximately $30,000 per year.

Particle size determinations would also have to be made at approximately 10 locations for a one-time equipment cost of $20,000, and would require one day per month of a technician and one-half day per month of a professional. In addition, to provide adequate monitoring, personal sampling pump assemblies would be required at a cost of $9,000 for the case study firm. All particulate air samples would have to be analyzed for isotopic content at a cost of $192,000 per year. (This includes personnel and laboratory cost estimated by case study mill.)

The computer software and hardware used for the evaluation of personnel exposures would also have to be upgraded. It is estimated that to modify the software, approximately six man-months of a programmer would be required. Hardware costs of $30,000 are estimated. Additionally, a full-time records clerk would have to be employed at an annual cost of $16,200.

---

[1] *Op. cit., ICRP-30.*

Table 37: Cost of Revised Internal Monitoring for a Large Mill
(Nominal Capacity 3,000 Tons Ore/Day)

		Unit Cost[a]	Initial	Annual
Solubility Measurement System				
- Professional for setup	.5 person/yrs.	$54,000	$27,000	
- Technician for monitoring	.5 person/yrs.	$27,000		$13,500
- Monitoring equipment			22,000	
- Laboratory support				30,000
Determination of Particle Size				
- Monitoring equipment			20,000	
- Professional analytic time	6 pers./days/yr.	$ 216		1,296
- Tech. data collection time	12 pers./days/yr.	$ 108		1,296
- Personal pump assemblies			9,000	
- Isotopic Analysis				192,000
Record-Keeping				
- Programmer	.5 person/yrs.	$34,000	17,000	
- Hardware			30,000	
- Records clerk	1 person/yr.			16,200
Total Cost			$125,000	$254,292

[a] Includes a 35 percent mill overhead rate.

The costs are summarized in Table 37. These estimates are based on data provided by the case study firm, which operates a large facility. Many of the costs anticipated by the mill will occur regardless of mill size (e.g., program set-up). Some costs are expected to be a function of the age and size of the facility, number of workers and expected capacity utilization. No data are available to develop specific cost estimates for each of the 20 facilities currently operating.[1] Therefore, the estimated cost for the case study mill will be assumed for each of the seven larger facilities (nominal capacity greater than 3,000 tons of ore per day); half the case study costs will be assumed for the seven midsized facilities (nominal capacity between 3,000 and 1,500 tons/day); and one quarter of the case study mill costs will be assigned for the six small facilities (nominal capacity less than 1,500 tons/day). Utilizing these assumptions, industry costs are estimated to be approximately $1,500,000 in initial costs and $3,062,000 in continuing annual costs.[1]

---

[1] *Op.cit., Statistical Data of the Uranium Industry*

Guidance #9 - Alternative Whole-body Limit - 1.5 rem/yr

The imposition of this alternative RPG would have a cost impact on the mill operations, particularly in light of the reduced intake limits. It is reasonable to conclude that there would be a problem in the precipitation and packaging area. In order to meet the guideline it would probably require a process change; i.e., a change to a slurry process. Moreover, it would possibly require additional people for health physics protection and to demonstrate compliance with the guidance. No firm cost estimate was provided by the case study mill and other data are not sufficient to develop a separate estimate. Therefore, it is assumed that the costs of the 1.5 rem/year limit will be the same as Range C requirements or $1.1 million annually.

14.3 SUMMARY OF COST OF COMPLIANCE

Impacts of the guidelines on the 20 currently operating uranium mills are expected to be concentrated in Range C compliance and in internal exposure control, monitoring, and recordkeeping. The addition of health physicists to the mill staff for compliance with Range C is estimated to cost $1 million annually. The determination and monitoring of particle size and solubility of materials and the development of a recordkeeping system for these data are expected to cost the industry $1.5 million to establish and $3 million annually to maintain. The alternate whole-body limit of 1.5 rem would result in costs equal to the Range C compliance costs.

---

[1] *Two firms (Pathfinder Mines and Union Carbide) operate two facilities each and thus could realize some economies in program development. However, such refinements are considered beyond the accuracy of the aggregate cost estimates provided.*

CHAPTER 15

COST OF COMPLIANCE: URANIUM CONVERSION PLANT

15.1 INDUSTRY PROFILE: URANIUM CONVERSION

This industry is comprised of two facilities that utilize distinctly different production processes. One plant produces uranium hexafluoride (UF_6) with a complex wet chemistry process at a rated output of 10,000 MT/yr and employs 160 people. The plant operates three shifts per day, seven days per week. The other conversion plant in operation utilizes a dry process and has a rated output of 14,000 MT/yr of UF_6. The raw material is uranium concentrate (yellowcake) and some yellowcake slurry is received from all uranium mills in the country. Both plants, due to the reduced demand for uranium in the nuclear power industry, are currently operating at reduced capacity.

The distinct production processes selected by these two plants will result in some unique radiation protection problems. However, a case study was conducted for only one facility. The personal at the case study facility indentified some of these differences, but felt that the total cost of compliance for the other facility would probably be similar to the cost for their facility. Hence we have utilized the cost estimates from the case study facility and applied them to the other facility to estimate industry impacts. Refinement of these estimates would be possible through an additional case study.

15.2 COST OF COMPLIANCE WITH GUIDANCE

Guidance #1 - Annual Whole-body Limit - 5 rem/yr

The revised limit is not expected to have an impact on this industry, at least with respect to external exposures. The highest whole body exposure in 1981 at the case study facility was less than one rem. Exposures reported to NRC[1] for the industry category that includes these facilities were all less than 3 rem.

---

[1] *Op. cit., NRC, NUREG-0714.*

Guidance #2 Accumulated Lifetime Expsoure - 100 Rem

The reduction of the accumulated exposure limit to 100 rem is not expected to have a cost impact at this plant. The highest accumulated exposure for plant personnel is considerably lower than the 100 rem limit.

Guidance #3 - Exposure to Extremities and Organs

No activities at the case study facility that would result in high extremity exposure were identified. Therefore, no impact is expected from the revised extremity limits other than some relatively low cost periodic extremity monitoring.

Guidance #4 - Anticipated Exposures in Range C (1.5 - 5 rem)

The whole-body exposures of all plant personnel at the case study plant have been maintained at less than 1.0 rem for the years 1979, 1980, and 1981, except for one employee in 1980. The main impact from the proposed guideline would be due to the new internal exposure limit. Some plant workers would be potentially exposed to airborne concentrations in excess of the revised insoluble uranium limit (RPG $1x10^{-11}$ uCi/me). The average annual exposures for the case study plant in each of the five process areas would range from 1.4 to 2.3 times the insoluble uranium limit for the year 1981. If the new guidance on internal exposures were to be imposed, it would be difficult to maintain combined exposures significantly below the limit. The difficulty in meeting the new internal limit is discussed later in this chapter.

Potential internal exposures are monitored by means of an extensive air sampling system in which 45 sampler heads are connected to a central vacuum and the filters changed after each eight-hour shift. The manager of Health Physics and Industrial Safety and five health physics technicians provide radiation protection services at the plant. It is anticipated that a certified health physicist, at a cost of $40,000 per year, would have to be employed to provide radiation protection, supervision in the plant areas in order to comply with the proposed Range C guidance. At an overhead factor of 1.35, a cost of $108,000 per year would be incurred by the industry.

Guidance #5- Anticipated Exposures in Range B (0.5 - 1.5 rem)

The case study plant is currently operating in full compliance with this proposed guidance. All personnel wear film badges to measure external exposures. Potential internal exposures are monitored with an extensive air sampling system. The manager of Health Physics and Industrial Safety and five health physics technicians maintain records on external sources of radiation and airborne concentrations in the six plant areas, and are available to monitor during non-routine operations. These professionals are expected to assure that exposures are justified and are ALARA.

Guidance #6 - Training

The existing training program satisfies the proposed guidance on training.

Guidance #7 - Exposure to the Unborn

At present, approximately 19 percent of the plant employees are females of child-bearing age. Presently the corporation management conforms to the policy as described in Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure." Accordingly, there is not expected to be a cost impact from Alternative a of the guidance for protection of the unborn. The proposed Alternative b is not considered to be a viable alternative at this plant since pregnant women are assigned to non-radiation areas. Alternative c might result in women not being considered for certain jobs, but neither have would result in cost impacts.

Guidance #8 - Internal Exposure

The current approach at the case study facility is to calculate time-weighted average exposure concentrations (TWA) based on mesured airborne concentrations of uranium and work location cards. The TWA is calculated for each person that routinely works in a process area and is recorded as a fraction of the MPC. Internal doses are not estimated unless the calculated airborne exposure is greater than 40 MPC-hrs/week for soluble uranium and 520 MPC-hrs/qtr. for insoluble uranium. These exposures are verified using the bioassay procedures described in the case study report and the results are recorded along with MPC-hrs. Measured external exposures obtained from the film badge readings are not currently added to the estimated internal exposures. A computer program at the plant is currently in place which provides output data for determining compliance with existing regulation.

Workers are potentially exposed to airborne concentrations in excess of the revised insoluble uranium limit (DAC of 2×10^{-11}uCi/ml).[1] For 1981, the average annual personnel exposures in each of the five process areas in the case study facility range from approximately 0.7 to 1.2 times the insoluble uranium DAC. The approach to compliance with the revised limits would require the calculation of potential exposure to uranium for each worker. The conservative assumptions currently made would have to be relaxed. In particular, measured particle sizes and solubilities would be used in the calculations.

Particle size distributions in air are presently not available for the facility. It is estimated that using actual measured particle size distributions would reduce calculated potential exposures by about 20 to 30 percent. Larger gains are potentially available from the use of measured solubility factors.

Determination of actual solubility fractions could lead to the relaxation of the conservative assumption of total insolubility (Class Y). The MPC's for soluble uranium are a factor of about 30 higher than those of insoluble uranium. It is estimated that using actual solubility class (i.e., Class W solubility) would lower the calculated potential exposures by about a factor of fifteen (i.e., Class Y to Class W).

Establishment of a routine system for measuring solubility fractions would take a professional approximately six person-months of effort. Then routine monitoring of this parameter is expected to take a technician approximately ten person-days each month. (It is assumed that NRC would require continual routine monitoring of this parameter.) The one time equipment cost for solubility fraction sampling is estimated by the case study plant to be approximately $22,000. Additionally, laboratory support is estimated to cost approximately $30,000 per year.

Particle size determinations would also have to be made at approximately 10 locations for a one-time equipment cost of $20,000, and would require one day per month of a technician and one-half day per month of a professional. In addition, to provide adequate monitoring, personal sampling pump assemblies would be required at a cost of $9,000 for the case study firm. All particulate air samples would have to be analyzed for isotopic content at a cost of $192,000 per year. (This includes personnel and laboratory cost estimated by case study plant.)

---

[1] *Op. cit., ICRP-30.*

The computer software and hardware used for the evaluation of personnel exposures would also have to be upgraded. It is estimated that to modify the software, approximately six man-months of a programmer would be required. Hardware costs of $30,000 are estimated. Additionally, a full-time records clerk would have to be employed at an annual cost of $16,200.

Table 38: Cost of Revised Internal Monitoring for a UF$_6$ Conversion Facility

		Unit Cost [a]	Initial	Annual
Solubility Measurement System				
- Professional for setup	.5 person/yrs.	$54,000	$27,000	
- Technician for monitoring	.5 person/yrs.	$27,000		$13,500
- Monitoring equipment			22,000	
- Laboratory support				30,000
Determination of Particle Size				
- Monitoring equipment			20,000	
- Professional analytic time	6 pers./days/yr.	$ 216		1,296
- Tech. data collection time	12 pers./days/yr.	$ 108		1,296
- Personal pump assemblies			9,000	
- Isotopic analysis				192,000
Record-Keeping				
- Programmer	.5 person/yrs.	$34,000	17,000	
- Hardware			30,000	
- Records clerk	1 person/yr.			16,200
Total Cost			$125,000	$254,292

---

[a] Includes a 35 percent overhead rate.

While there is some uncertainty as to the costs for the other plant, it is anticipated that it also will have to undergo changes in the calculation procedures to show compliance with the internal dose revisions to the guidance. Therefore, as a crude estimate, total costs for the industry are expected to be approximately double the one plant cost or $250,000 initially and $500,000 annually.

Guidance #9 - Alternative Whole-body Limit - 1.5 rem/yr.

The imposition of this alternative limit would have a cost impact on the conversion plant operations, given the parallel imposition of the reduced intake limits. There would probably have to be process changes and/or increased confinement on certain operations. Moreover, considerably more effort would have to be expended on this radiation protection program. No data are available to calculate such costs. Therefore, the cost of compliance with Range C will be utilized as $108,000.

15.3 SUMMARY OF COST OF COMPLIANCE

Only two uranium conversion facilities currently operate in the U.S. Impacts from the Range C requirements are estimated to cost the industry $100,000 per year for the expansion of the health physics staff. The development of a particle size and solubility monitoring and recording system to comply with the internal exposure guidance is expected to cost the industry $250,000 initially and $500,000 annually.

CHAPTER 16

COST OF COMPLIANCE: OTHER INDUSTRIES

16.1 INDUSTRY PROFILE: OTHER INDUSTRIES

Education

According to the 1975 survey,[1] there were an estimated 111,600 individuals (including 89,800 students) potentially exposed in this category, 37,200 of which (including 30,000 students) received measurable exposures. Of the 18,253 individuals monitored in 1978 by NRC academic licensees (388 of them), only 76 (0.4%) received exposures in excess of 1.0 rem and 223 (1.2%) were exposed in excess of 0.5 rem. Therefore the impacts of the Range C requirements, and possibly even those of Range B, as well as the alternative guidelines relating to exposure of the unborn, are expected to be minimal. The only significant cost might be for training of students and staff.

Private Medical — Other Than Radiologists

Other than the practice of radiology (including nuclear medicine), occupational exposure occurs in practices operating their own X-ray machines. Included are podiatry, chiropractic medicine, and veterinary medicine (as well as orthopedics, gastroenterology, urology, and pediatrics. According to the 1975 survey, there were 42,800 workers in podiatry, chiropratic medicine, and veterinary medicine with 12,000 of them receiving measurable exposures. With the exception of veterinary medicine, exposures should be in Range A if equipment is operating properly and procedures are followed. Under these conditions, the only element of the proposed guidelines that could impose a cost is that of training, since it is unlikely that the workers in these offices are uniformly instructed in the principles of radiation protection or on levels of risk. However, approximately 3% of recorded annual whole-body exposures in veterinary medince were in excess of 0.5 rem in 1975. Therefore, Range B exposures are anticipated in this industry. This would require monitoring by part-time health physicists at each veterinary practice. According to the 1979 Census, there were 10,403 veterinary establishments in 1978.

---

[1] Op. cit. EPA, 1980, EPA 520/4-80-001.

Users of Industrial Gauges

This category potentially involves a very large number of firms; however, the impact of the proposed guidelines, with the possible exception of the training requirements, is expected to be small. In 1978, there were 2555 NRC licensees in this category ("Other Measuring Systems"), with possibly an equal number of Agreement State licensees. The average number of monitored workers per NRC licensee was approximately nine. Only 0.2% of those monitored received annual exposures in excess of 1.0 rem, and less than 0.6% received annual exposures in excess of 0.5 rem. Therefore, the impacts from Range B and C requirements, and from the exposure to unborn alternatives, are expected to be minimal.

Operators of Irradiators

In 1978, there were 228 firms licensed by the NRC to operate irradiators, 53 of which possessed sources in excess of 10,000 Ci. It may be assumed that there were an equal number of Agreement State irradiator licensees. The average number of monitored workers per NRC license was approximately 17. Of the workers monitored by NRC licensees, only about 24% received measurable exposures. Furthermore, only approximately 0.5 percent received annual exposures in excess of 1.0 rem and roughly 1.3% were exposed to more than 0.5 rem per year. Therefore, the Range, C, Range B, and exposure to the unborn requirements would be expected to have minimal impact. It is expected that most employees of irradiator licensees already receive instruction in radiation protection principles, although instruction in levels of risk is probably not generally included.

Transportation

According to the 1975 Survey, there were 77,000 workers potentially exposed to ionizing radiation in the transportation category, approximately 12,000 of which received measurable exposures. The average exposure was low, approximately 0.030 rem. However, there may be as many as 500 independent truck drivers who ship radiopharmaceuticals and receive doses in excess of 0.5 rem per year. Some of these truck drivers may even receive exposures in Range C. It is unlikely that a significant number of these truck drivers are female. It is also unlikely that a significant number of individuals the transportation category currently obtain instruction in radiation protection principles or levels of risk. In summary, there certainly would be compliance costs in transportation. At this time, however, sufficient information is not available to estimate the magnitude of the impact of the guidance.

APPENDIX A

Reprint from Federal Register - 5/18/60

Federal Register - 1/23/81

FEDERAL RADIATION COUNCIL

RADIATION PROTECTION GUIDANCE FOR FEDERAL AGENCIES

Memorandum for the President

Pursuant to Executive Order 10831 and Public Law 86-373, the Federal Radiation Council has made a study of the hazards and use of radiation. We herewith transmit our first report to you concerning our findings and our recommendations for the guidance of Federal agencies in the conduct of their radiation protection activities.

It is the statutory responsibility of the Council to "* * * advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States * * *"

Fundamentally, setting basic radiation protection standards involves passing judgment on the extent of the possible health hazard society is willing to accept in order to realize the known benefits of radiation. It involves inevitably a balancing between total health protection, which might require foregoing any activities increasing exposure to radiation, and the vigorous promotion of the use of radiation and atomic energy in order to achieve optimum benefits.

The Federal Radiation Council has reviewed available knowledge on radiation effects and consulted with scientists within and outside the Government. Each member has also examined the guidance recommended in this memorandum in light of his statutory responsibilities. Although the guidance does not cover all phases of radiation protection, such as internal emitters, we find that the guidance which we recommend that you provide for the use of Federal agencies gives appropriate consideration to the requirements of health protection and the beneficial uses of radiation and atomic energy. Our further findings and recommendations follow.

Discussion. The fundamental problem in establishing radiation protection guides is to allow as much of the beneficial uses of ionizing radiation as possible while assuring that man is not exposed to undue hazard. To get a true insight into the scope of the problem and the impact of the decisions involved, a review of the benefits and the hazards is necessary.

It is important in considering both the benefits and hazards of radiation to appreciate that man has existed throughout his history in a bath of natural radiation. This background radiation, which varies over the earth, provides a partial basis for understanding the effects of radiation on man and serves as an indicator of the ranges of radiation exposures within which the human population has developed and increased.

The benefits of ionizing radiation. Radiation properly controlled is a boon to mankind. It has been of inestimable value in the diagnosis and treatment of diseases. It can provide sources of energy greater than any the world has yet had available. In industry, it is used as a tool to measure thickness, quantity or quality, to discover hidden flaws, to trace liquid flow, and for other purposes. So many research uses for ionizing radiation have been found that scientists in many diverse fields now rank radiation with the microscope in value as a working tool.

The hazards of ionizing radiation. Ionizing radiation involves health hazards just as do many other useful tools. Scientific findings concerning the biological effects of radiation of most immediate interest to the establishment of radiation protection standards are the following:

1. Acute doses of radiation may produce immediate or delayed effects, or both.

2. As acute whole body doses increase above approximately 25 rems (units of radiation dose), immediately observable effects increase in severity with dose, beginning from barely detectable changes, to biological signs clearly indicating damage, to death at levels of a few hundred rems.

3. Delayed effects produced either by acute irradiation or by chronic irradiation are similar in kind, but the ability of the body to repair radiation damage is usually more effective in the case of chronic than acute irradiation.

4. The delayed effects from radiation are in general indistinguishable from familiar pathological conditions usually present in the population.

5. Delayed effects include genetic effects (effects transmitted to succeeding generations), increased incidence of tumors, lifespan shortening, and growth and development changes.

6. The child, the infant, and the unborn infant appear to be more sensitive to radiation than the adult.

7. The various organs of the body differ in their sensitivity to radiation.

8. Although ionizing radiation can induce genetic and somatic effects (effects on the individual during his lifetime other than genetic effects), the evidence at the present time is insufficient to justify precise conclusions on the nature of the dose-effect relationship at low doses and dose rates. Moreover, the evidence is insufficient to prove either the hypothesis of a "damage threshold" (a point below which no damage occurs) or the hypothesis of "no threshold" in man at low doses.

9. If one assumes a direct linear relation between biological effect and the amount of dose, it then becomes possible to relate very low dose to an assumed biological effect even though it is not detectable. It is generally agreed that the effect that may actually occur will not exceed the amount predicted by this assumption.

Basic biological assumptions. There are insufficient data to provide a firm basis for evaluating radiation effects for all types and levels of irradiation. There is particular uncertainty with respect to the biological effects at very low doses and low-dose rates. It is not prudent therefore to assume that there is a level of radiation exposure below which there is absolute certainty that no effect may occur. This consideration, in addition to the adoption of the conservative hypothesis of a linear relation between biological effect and the amount of dose, determines our basic approach to the formulation of radiation protection guides.

The lack of adequate scientific information makes it urgent that additional research be undertaken and new data developed to provide a firmer basis for evaluating biological risk. Appropriate member agencies of the Federal Radiation Council are sponsoring and encouraging research in these areas.

Recommendations. In view of the findings summarized above the following recommendations are made:

It is recommended that:

1. There should not be any man-made radiation exposure without the expectation of benefit resulting from such exposure. Activities resulting in man-made radiation exposure should be authorized for useful applications provided in recommendations set forth herein are followed.

It is recommended that:

2. The term "Radiation Protection Guide" be adopted for Federal use. This term is defined as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable.

It is recommended that:

3. The following Radiation Protection Guides be adopted for normal peacetime operations:

Type of exposure	Condition	Dose (rem)
Radiation worker:		
(a) Whole body, head and trunk, active blood forming organs, gonads, or lens of eye.	Accumulated dose	5 times the number of years beyond age 18.
	13 weeks	3.
(b) Skin of whole body and thyroid	Year	30.
	13 weeks	10.
(c) Hands and forearms, feet and ankles	Year	75.
	13 weeks	25.
(d) Bone	Body burden	0.1 microgram of radium-226 or its biological equivalent.
(e) Other organs	Year	15.
	13 weeks	5.
Population:		
(a) Individual	Year	0.5 (whole body).
(b) Average	30 year	5 (gonads).

The following points are made in relation to the Radiation Protection Guides herein provided:

(1) For the individual in the population, the basic Guide for annual whole body dose is 0.5 rem. This Guide ap-

plies when the individual whole body doses are known. As an operational technique, where the individual whole body doses are not known, a suitable sample of the exposed population should be developed whose protection guide for annual whole body dose will be 0.17 rem per capita per year. It is emphasized that this is an operational technique which should be modified to meet special situations.

(2) Considerations of population genetics impose a per capita dose limitation for the gonads of 5 rems in 30 years. The operational mechanism described above for the annual individual whole body dose of 0.5 rem is likely in the immediate future to assure that the gonadal exposure Guide (5 rem in 30 years) is not exceeded.

(3) These Guides do not differ substantially from certain other recommendations such as those made by the National Committee on Radiation Protection and Measurements, the National Academy of Sciences, and the International Commission on Radiological Protection.

(4) The term "maximum permissible dose" is used by the National Committee on Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP). However, this term is often misunderstood. The words "maximum" and "permissible" both have unfortunate connotations not intended by either the NCRP or the ICRP.

(5) There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It should be general practice to reduce exposure to radiation, and positive effort should be carried out to fulfill the sense of these recommendations. It is basic that exposure to radiation should result from a real determination of its necessity.

(6) There can be different Radiation Protection Guides with different numerical values, depending upon the circumstances. The Guides herein recommended are appropriate for normal peacetime operations.

(7) These Guides are not intended to apply to radiation exposure resulting from natural background or the purposeful exposure of patients by practitioners of the healing arts.

(8) It is recognized that our present scientific knowledge does not provide a firm foundation within a factor of two or three for selection of any particular numerical value in preference to another value. It should be recognized that the Radiation Protection Guides recommended in this paper are well below the level where biological damage has been observed in humans.

It is recommended that:

4. Current protection guides used by the agencies be continued on an interim basis for organ doses to the population.

Recommendations are not made concerning the Radiation Protection Guides for individual organ doses to the population, other than the gonads. Unfortunately, the complexities of establishing guides applicable to radiation exposure of all body organs preclude the Council from making recommendations concerning them at this time. However, current protection guides used by the agencies appear appropriate on an interim basis.

It is recommended that:

5. The term "Radioactivity Concentration Guide" be adopted for Federal use. This term is defined as the concentration of radioactivity in the environment which is determined to result in whole body or organ doses equal to the Radiation Protection Guide.

Within this definition, Radioactivity Concentration Guides can be determined after the Radiation Protection Guides are decided upon. Any given Radioactivity Concentration Guide is applicable only for the circumstances under which the use of its corresponding Radiation Protection Guide is appropriate.

It is recommended that:

6. The Federal agencies, as an interim measure, use radioactivity concentration guides which are consistent with the recommended Radiation Protection Guides. Where no Radiation Protection Guides are provided, Federal agencies continue present practices.

No specific numerical recommendations for Radioactivity Concentration Guides are provided at this time. However, concentration guides now used by the agencies appear appropriate on an interim basis. Where appropriate radioactivity concentration guides are not available, and where Radiation Protection Guides for specific organs are provided herein, the latter Guides can be used by the Federal agencies as a starting point for the derivation of radioactivity concentration guides applicable to their particular problems. The Federal Radiation Council has also initiated action directed towards the development of additional Guides for radiation protection.

It is recommended that:

7. The Federal agencies apply these Radiation Protection Guides with judgment and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The Guides may be exceeded only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this paper.

The Radiation Protection Guides provide a general framework for the radiation protection requirements. It is expected that each Federal agency, by virtue of its immediate knowledge of its operating problems, will use these Guides as a basis upon which to develop detailed standards tailored to meet its particular requirements. The Council will follow the activities of the Federal agencies in this area and will promote the necessary coordination to achieve an effective Federal program.

If the foregoing recommendations are approved by you for the guidance of Federal agencies in the conduct of their radiation protection activities, it is further recommended that this memorandum be published in the Federal Register.

Arthur S. Flemming,
Chairman,
Federal Radiation Council.

The recommendations numbered "1" through "7" contained in the above memorandum are approved for the guidance of Federal agencies, and the memorandum shall be published in the Federal Register.

Dwight D. Eisenhower

May 13, 1960.

[F.R. Doc. 60-4530; Filed, May 17, 1960; 8:51 a.m.]

federal register

Friday
January 23, 1981

Part XV

Environmental Protection Agency

Federal Radiation Protection Guidance for Occupational Exposures

[RH-FRL 1722-5]

Federal Radiation Protection Guidance for Occupational Exposures; Proposed Recommendations, Request for Written Comments, and Public Hearings

AGENCY: U.S. Environmental Protection Agency.

ACTION: Proposed recommendations for radiation protection of workers.

SUMMARY: We are proposing to make recommendations to the President for new guidance to Federal agencies for the protection of workers exposed to ionizing radiation. These proposals are based on a review of existing guidance in the light of scientific knowledge of radiation risks and of experience in the control of occupational exposure. The proposed recommendations include both qualitative guidance on radiation protection and numerical guides for maximum allowed dose equivalents (RPG's[1]). The most significant changes proposed are (a) that a graded set of minimum radiation protection requirements be introduced in three levels; (b) that the RPG for maximum whole-body dose equivalent be reduced from three rem[2] per quarter to five rem per year, and that regulatory agencies establish lower limits for specific types of work situations; (c) that limitation of internal doses[3] take into account the sum of the risks to all organs, rather than continue to be based only on the most significantly exposed organ; (d) that the RPGs for the whole body apply to the appropriately weighted sum of the doses from both internal and external exposures; and (e) that the dose to the embryo and the fetus be limited through one of several alternative recommendations.

We welcome written comments on these proposals and will hold public hearings as discussed below. We will carefully consider all oral and written comments in preparing our final recommendations to the President.

DATES: 1. All written comments in response to this notice must be received by us by April 24, 1981, in order to be used.

2. Public hearings will be held at the following locations, beginning no earlier than 60 days following publication of this notice: Washington, D.C., Chicago, Illinois, San Francisco, California, Houston, Texas. We will publish the times and addresses for these hearings shortly.

3. Instructions of interest to those who wish to appear at the public hearings are given below under the heading "Public Hearings."

ADDITIONAL INFORMATION: We will be happy to send a copy of a background report which provides additional information on these proposed recommendations to anyone requesting it. Please send requests to Mr. Luis F. Garcia at the address below. This report is also available for inspection and copying at EPA's Central Docket Section and ten Regional Offices (addresses below).

ADDRESSES: Written comments should be addressed to the Director, Criteria and Standards Division (ANR-460), U.S. Environmental Protection Agency, Washington, D.C. 20460, Attention: Docket No. A-79-46. These comments and the public hearing record will be filed under the above docket number and will be available for inspection and copying at the U.S. Environmental Protection Agency's Central Docket Section, Room 2903B, Mall 401 M Street, S.W., Washington, D.C. 20460, and at the Agency's library in each of its ten regional offices: *Region I:* JFK Building, Room 2100-B; Boston, Massachusetts 02203 (Tel. 617-223-5791); *Region II:* 26 Federal Plaza, Room 1002, New York, New York 10278 (Tel. 212-264-2881); *Region III:* Curtis Building, 6th & Walnut Streets, Philadelphia, Pennsylvania 19106 (Tel. 215-597-0580); *Region IV:* 345 Courtland Street, N.E., Atlanta, Georgia 30365 (Tel. 404-881-4216); *Region V:* 230 South Dearborn Street, Room 1417, Chicago, Illinois 60604 (Tel. 312-353-2022); *Region VI:* First International Building, 1201 Elm Street, 28th Floor, Dallas, Texas 75270 (Tel. 214-767-7341); *Region VII:* 324 East 11th Street, Kansas City, Missouri 64106 (Tel. 816-374-3497); *Region VIII:* Radiation Program Office (in lieu of library), 1860 Lincoln Street, Second Floor, Denver, Colorado 80203 (Tel. 303-837-2221); *Region IX:* 215 Fremont Street, 6th Floor, San Francisco, California 94105 (Tel. 415-556-1841: *Region X:* 1200 Sixth Avenue, 12th Floor, Seattle, Washington 98101 (Tel. 206-442-1289).

FOR FURTHER INFORMATION CONTACT: Contact Mr. Luis F. Garcia, U.S. Environmental Protection Agency (ANR-460), Washington, D.C. 20460 (Telephone 703-557-8224), about these proposed recommendations or the public hearings.

SUPPLEMENTARY INFORMATION:

Statutory Authority

The Administrator of the Environmental Protection Agency (EPA) is charged under Executive Order 10831, Reorganization Plan No. 3 of 1970, and Public Law 86-373 to "* * * advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States." This guidance has historically taken the form of qualitative and quantitative "Radiation Protection Guidance." The recommendations we propose here would replace those portions of existing Federal guidance that apply to radiation protection of workers, which were adopted in 1960 (25 FR 4402).

Previous Actions by EPA

We began this review of the 1960 radiation protection guidance for workers in 1974. The most recent notice of this activity listed the principal issues being addressed and announced our intent to hold public hearings on proposed recommendations (44 FR 53785, Sept. 17, 1979).

We have sponsored two major studies in support of this program. First, the Committee on the Biological Effects of Ionizing Radiations, National Academy of Sciences—National Research Council, has reviewed the scientific data on the health risks of low level ionizing radiation developed since its 1972 report. Second, we have carried out a study of occupational radiation exposures and published our findings in a report entitled: "Occupational Exposure to Ionizing Radiation in the United States: A Comprehensive Summary for the Year 1975." We have also considered recent recommendations of the National Council on Radiation Proctection and Measurements.

In developing these proposals, we have also consulted with the technical staffs of the Federal agencies that regulate or influence the regulation of occupational exposure, and will continue this consultation in developing final recommendations. These agencies are the Occupational Safety and Health Administration, the Nuclear Regulatory Commission, the Mine Safety and Health Administration, the Department of Defense, the Department of Energy, the Department of Transportation, the Food and Drug Administration, the National Aeronautics and Space Administration, the National Institute for Occupational Safety and Health, and the National Bureau of Standards. These agencies, which have not formally endorsed these recommendations, will formally review final proposals when they are developed following public review.

---

[1] Radiation Protection Guides.

[2] A *rad* is a unit of measure for dose, i.e., the amount of ionizing radiation energy absorbed per unit weight of tissue. Thus, the same energy absorbed by twice as much tissue gives only one-half the number of rads. The *rem*, a unit for dose equivalent, is a rad multiplied by factors which describe how damaging the type of radiation is.

[3] In this notice we henceforth use "dose" to mean "dose equivalent."

Issues Addressed

The principal issues we addressed in formulating these recommendations were identified in the advance notice cited above. They were:

1. Are the doses currently received by workers and the maximum doses permitted under existing guidance adequately low? In this regard, a) how adequate is the basis used for estimating risks to health from radiation exposure, and b) what are the appropriate bases for judging maximum individual and collective radiation doses in the work force and the tradeoffs between these two indices of the health impact of occupational exposure?

2. Should the same guides apply to all categories of workers (e.g., dental workers, nuclear medicine technicians, nuclear maintenance personnel, industrial radiographers)? Should specific guides be developed for pregnant women, female workers who could bear children, and/or men?

3. On what time basis should the guides be expressed? Quarterly? Annual? Should the lifetime occupational dose be limited? Should the age of the worker be a factor?

4. Should the guidance reflect or cover medical, accidental, and/or emergency exposures?

5. Is existing guidance for situations that involve exposure of less than the whole body adequate? In this respect, a) what organs and parts of the body should have designated limits, and b) on what basis should guidance be expressed for exposure of more than one organ or portion of the body?

6. How should the radiation protection principles requiring a) justification of any exposure, and b) reduction of the dose from justified exposures to the lowest practicable or as low as is reasonably achievable level be applied to exposure of workers? Should the concept of lowest feasible level be applied to exposure of workers?

7. What, if any, relationship should be maintained between permissible levels of risk to health from radiation exposure and other regulated hazards of disease or accidents?

Additional issues suggested since publication of the advance notice include:

8. Should the guidance include numerical values for the factors (called "quality" and "modifying" factors) used to convert dose (measured in rads) to dose equivalent (measured in rem)? If so, should this be developed now or issued later as supplementary guidance?

9. What guidance should apply to workers who do not use radiation sources, but who are exposed to radiation due to the activities of workers under the control of other employers?

10. Are there situations that may require doses higher than normally permitted? Should we provide special guidance for them?

Many of these issues are addressed below. However, for a more complete and extensive discussion please refer to the background report cited above under the heading "Additional Information."

Risks From Occupational Exposure

There are three kinds of risks from the low levels of ionizing radiation characteristic of occupational exposures. The most important of these is cancer, which is fatal at least half the time. Another risk is the induction of hereditary effects in descendants of exposed persons. The severity of these effects ranges from fatal to inconsequential. We assume that at low levels of exposure the risk of cancer and hereditary effects is in proportion to the dose received, and that the severity of any induced effect is independent of the dose level. That is, while the probability of a given type of cancer occurring increases with dose, such a cancer induced at one dose is equally as debilitating as that same type of cancer induced at another dose. Thus, for these effects we assume that there is no completely risk-free level of radiation exposure.

The third type of risk includes a variety of other effects on workers and on the children of women exposed during pregnancy. These effects range from serious effects on children, such as mental retardation, to less serious effects on workers, such as opacification of the lens of the eye and temporary impairment of fertility. For these effects we believe the degree of damage (i.e., the severity) depends to some extent on the dose level. At the dose levels allowed by current radiation protection guides, we believe that none of the effects on workers themselves occurs to a degree sufficient to be clinically detectable. At these levels, however, effects on children exposed in utero may be serious.

The risks of effects on health from low level ionizing radiation were reviewed for EPA by the National Academy of Sciences (NAS) in reports published in 1972 and in 1980. We have used these studies and others to estimate the risks associated with the current and proposed Federal guides for limiting radiation dose. Details of these and other risk estimates we use are provided in the accompanying background report.[4]

A worker who received the largest lifetime dose allowed under present guides (5 rem per year from age 18 to assumed retirement at age 65, or 235 rem) would have a lifetime risk of about 3 to 6 in 100 of dying from radiation-induced cancer, and numerically comparable chances both of nonfatal cancer and, for male workers, of mutational effects in his descendants.[5] Risks of mutational effects from exposure of female workers are assumed to be three to four times smaller. However, in our recent national survey of exposures for the year 1975, 99% of all workers received less than half of, and only 0.15% exceeded, an annual dose of 5 rem. Based on these and other data, we believe that only a few workers involved in accidents have received close to the current maximum allowed lifetime dose.

The average worker exposed to radiation sustains only a small risk of death from radiation. The estimated average risk of death due to radiation-induced cancer is smaller, for example, than the risk of job-related accidental death in the safest of all major occupational categories, retail trades, for which the annual death rate was 60 per million workers in 1975. We estimate that the collective dose to the more than one million workers potentially exposed to radiation in their workplace for that same year will not lead to more than 15–36 premature cancer deaths. Other ways of expressing this risk are that the exposure of an average worker to radiation in 1975 represented an average lifeshortening of about two to three and a half hours, or an average increase in his chance of cancer death of about one to three in 100,000. In 1975 about one sixth of United States deaths were from cancer.

The comparative time-loss associated with nonfatal cancer is also estimated to be very small. The average time lost by

---

[4] Our estimated ranges of risk for cancer death are based on absolute and relative linear risk models used by the 1972 BEIR Committee and the assumption that the risk of incurring most radiogenic cancers continues throughout the lifetime of exposed persons. The 1980 BEIR report, which was just published, gives estimates based on a variety of risk models, some of which yield lower and some higher values. Based on our preliminary review, we do not believe that the differences between these values and those we have adopted here would lead to any changes in these proposals.

[5] Mutational effects here mean those hereditary effects included by the BEIR Committee in their 1972 report as serious disabilities. Examples are congenital malformations leading to premature death, hemophilia, sickle cell anemia, cystic fibrosis, diabetes, schizophrenia, and epilepsy.

U.S. workers due to all occupationally-related injuries and illnesses over a working lifetime is one month. For radiation-induced nonfatal cancers it is estimated to be about four days for a hypothetical individual receiving the largest lifetime dose allowed (235 rem), and for the average worker it is about two hours.

Limitation of Whole Body (External) Exposure

Based on these observations, risks due to occupational exposure to radiation do not appear to be unreasonably high for the average worker. They are comparable to risks of accidental death in the least hazardous occupations. However, a worker exposed to the current maximum allowed dose year after year would sustain substantial risks. The proposed radiation protection guidance contains provisions to avoid the accumulation of large lifetime doses through reduction of the maximum allowed annual dose and through specific minimum radiation protection requirements for workers in high-dose work situations. These include on-the-job radiation protection supervision for high-dose jobs, maintenance of lifetime dose records, and an admonition that exposure of workers should be managed so that their lifetime doses do not exceed 100 rem.

Existing Federal guidance permits doses up to 3 rem per quarter (or 12 rem per year), within an overall cumulative limit of 5(N–18) rem, where N is the age of the worker. This flexibility, which allows annual doses greater than 5 rem, does not permit specific tasks that require doses to individuals of more than 5 rem (since the 3 rem per quarter limit prohibits this), but it does permit the same worker to accomplish several tasks requiring doses at or near this quarterly limit in a given year. In view of the risks, it is our judgement that repeated exposures in a year at such levels should not occur, and these recommendations would eliminate this flexibility. One appropriate solution in cases where workers with specific skills are in short supply is to train additional workers, rather than to impose higher risks on a few individuals.

Because we assume that any exposure carries some risk, we believe that it is important to avoid unnecessary exposures at any exposure level. Although more than 97% of all workers in our survey received annual doses less than one rem, these same workers accumulated about half of the collective dose received by the entire work force. Many of these workers, because their doses are low compared to the limits, may receive only minimal training, supervision, and monitoring for radiation protection. Many also work in situations where there is no need for exposures to ever approach the existing or the proposed new RPGs. On the other hand, some exposures at higher doses are justified. The proposed recommendations, therefore, provide a graded system of radiation protection which would establish minimum radiation protection requirements for each of three different ranges of exposure within the basic guides for maximum allowed dose to all workers. We anticipate that maximum exposure of the vast majority of workers would be effectively limited to the lowest of these ranges (less than approximately 0.5 rem to the whole body per year) through the deterrent of requirements for increased justification, on-the-job radiation protection supervision, and monitoring in the two higher ranges. In addition, the recommendations encourage regulatory agencies to establish more restrictive regulatory limits for work situations not requiring the maximum doses allowed under the basic guides.

The proposed guidance leaves agencies considerable discretion in implementing the minimum radiation protection requirements for justification of exposure of workers in each of the various ranges. We are considering additional guidance which would recommend the establishment of more explicit requirements for the highest range (Range C). These requirements could include establishment of criteria for use of Range C, or prior application to and approval by the regulatory agency of Range C exposure (either for specific or more general job situations). We request specific comments on these and similar approaches to further restrictions on the exposure of workers at these higher levels.

We have considered both higher and lower alternatives to the proposed 5 rem/year RPG for whole-body exposure. This value is proposed because (a) it is the current internationally-accepted value, (b) there appear to be essential jobs requiring near 5 rem per year, and (c) the risks to the few workers in these jobs are not high compared to other industrial hazards. In addition, the costs for levels significantly lower (one rem/year or less) appear to be unwarranted, both in terms of increased collective dose to the entire workforce (in return for a few lower individual doses), and in terms of increased economic costs.

In 1975 the National Council on Radiation Protection and Measurements took the position that no change was required in the recommendation given by it in 1971. That recommendation is that "The maximum permissible prospective dose equivalent for whole body irradiation from all occupational sources shall be 5 rems in any one year" (NCRP Report No. 39, Jan. 15, 1971). Likewise the International Commission on Radiological Protection in 1977 recommended a basic dose-equivalent annual limit of 5 rem for whole body exposures to ionizing radiation (ICRP Publication 26, Jan. 17, 1977). In support of its recommendation the ICRP states that "The Commission believes that for the foreseeable future a valid method for judging the acceptability of the level of risk in radiation work is by comparing this risk with that for other occupations recognized as having high standards of safety, * * *." The radiation risk factors given in ICRP Publication 26 in arriving at its recommendation were reviewed by ICRP in May 1978 and no changes were made (ICRP Publication 28, 1978).

Nevertheless, these recommendations are all value judgments; there is not now compelling evidence for any particular value and it is hard to get such evidence. In judging the acceptability of the risks involved, it is necessary to identify (a) activities that cannot be performed at particular maximum dose levels, (b) skilled professionals and workers in limited supply whose numbers would be difficult to quickly increase in order to reduce average annual doses, and (c) the costs for additional workers and equipment that would be needed to meet different limits. For example, we are aware of a small number of maintenance tasks at nuclear power stations that could not be done under some limits less than 5 rem/year. There may be many more examples of professions, principally in medical areas, with limited labor pools. These include cardiologists performing catheterizations using fluoroscopy; and radiologists, neuro-radiologists, and nuclear medicine technologists with large patient loads for special procedures. Finally, studies by the Department of Energy and the nuclear power industry report that large costs and many more workers would be needed to greatly reduce the dose limits for many operations. Their projections of costs and personnel requirements increase expotentially with decreasing limits. We therefore request, in addition to comment on reduction of the current RPG of 3 rem/quarter to our proposed recommendation of 5 rem/year, comment on the above factors for reduction of the current RPG to 0.5 rem/year, 1 rem/year, and 3 rem/year.

Limitation of Partial Body Exposures

Exposure of portions of the body can occur through localized irradiation of extremities (such as hands in glove boxes), or by breathing or swallowing radioactive materials, which then migrate to different organs of the body.

Current guidance limits such exposures through separate numerical guides for organs and for individual parts of the body that are easily exposed, such as hands and feet or lens of the eye. Some organs recognized as easily subjected to high doses or as particularly sensitive to radiation have specific guides.

These current guides are applied separately. For example, even though a worker has received the maximum allowed dose to his thyroid, he may also receive doses to his lungs, skin, or any other organ, as long as no single organ receives more than the dose specified by its guide. We assume that the risks associated with such multiple doses are additive.

An alternative approach is to limit the total risk of fatal cancer in all exposed organs. This method has been adopted by the International Commission on Radiological Protection (ICRP). It is also adopted in these recommendations, but only when it leads to a greater degree of protection than limiting the dose to critical organs. Specifically, the recommended guidance provides that (a) either the combined risk of fatal cancer from all doses to individual organs not exceed the risk permitted under the whole body guide or (b) the dose to the most significantly exposed organ not exceed its guide, whichever is more restrictive. The recommendations also provide, when workers receive both external doses from whole-body exposure and internal doses from radionuclides, that the sum of the risks of fatal cancer from external whole-body doses and those due to breathing or swallowing radioactive materials not exceed the risk of fatal cancer allowed by the whole-body guide.

The numerical weighting factors chosen to relate risks to individual organs to whole-body risk are discussed in the background report cited above. In general, they are consistent with recent determinations of risk of fatal cancer by national and international scientific bodies, such as the NAS and the ICRP.

We have chosen the limiting annual dose to most single organs to be 30 rem, rather than the internationally-adopted value of 50 rem, because we do not see a need for a value higher than any now used in this country. The risk associated with 30 rem to any of these organs is equal to or less than that of 5 rem to the whole body. Additional differences from internationally-used values for gonads, lens of eye, and hands are discussed below.

It is usually impractical to directly monitor the dose received by a worker who breathes or swallows radioactive materials, but it is useful to be able to predict doses that may be received from breathing contaminated atmospheres or swallowing contaminated materials. To make decisions about radiation protection of such workers possible, it is necessary to calculate the amounts of different kinds of radioactive materials which, when breathed in or swallowed, give the maximum dose allowed by the RPGs. Those calculations require complex models of metabolism and dosimetry. We propose that these limiting amounts of radioactivity be designated the "Radioactivity Intake Factors" (RIFs), and that they replace the currently used "Radioactivity Concentration Guides."

Recent advances in modeling metabolism and dosimetry have produced significant changes in the doses calculated for radioactive materials in the body. For many radioactive materials the changes in the RIFs due to changes in the models are considerably larger than the changes due to the proposed new RPGs. These new models more often reduce allowable intakes than raise them. However, for those cases where the RIF for any specific radionuclide would be increased, the question arises whether regulations adopted by implementing agencies should retain existing values, in accordance with proposed Recommendations 2 and 6. We believe that, for existing applications, experience gained over the past two decades shows that current values can be reasonably achieved. Accordingly, in cases where the RIF for any specific radionuclide would be increased under the proposed guidance, we recommend that the value adopted in regulations governing existing applications be no higher than that now in use. A summary of the changes due to the new models and to the proposed new guides is provided for the more significant radionuclides in the background report.

Limitation of Risk From Mutations

The current guides for limiting dose to the gonads are identical to those for the whole body. For a given annual dose, the risk of mutational effects in all of a male worker's descendants combined is believed to be numerically comparable to his lifetime risk of fatal cancer. The risk to a female worker's descendants is smaller. The medical severity of these hereditary effects is usually less than, and, at worst, comparable to, death from cancer. For these reasons we do not believe that a more restrictive guide is required for the gonads than for the whole body. The proposed new guide for gonadal dose is therefore identical to that proposed for the whole body. This guide is specified separately and not included in the scheme proposed above for weighting partial-body doses because the risks involved are of a fundamentally different nature: the affected individual is not the one exposed to radiation and the effects include different types of harm.

Limitation of Risk to the Unborn (Fertilized Oocyte, Embryo, and Fetus

Protection of the unborn from radiation is an already well-established principle; the purpose of the guide for gonadal exposure is to limit mutational effects in children conceived after the exposure. However, those conceived but not yet born, the "unborn," are also at risk. Their risks are greater, for a given dose, than the risks to those not yet conceived. Current guidance does not contain a dose limitation to protect the unborn from these risks.

The risk of serious harm following in utero exposure requires careful attention because of the magnitude and diversity of the effects, because they occur so early in life, and because those who suffer the harm are involuntarily exposed. These risks are not as well quantified as those to adults. Nevertheless, available evidence indicates that at critical periods in the development of the unborn, for the same dose, risks may be many times greater than those to adults.

There are several factors which mitigate this situation. First, the exposure of most workers under annual limits is relatively evenly distributed over the year, so that only a quarter of a worker's annual dose is delivered to the unborn during any trimester. Second, the mother's body provides considerable shielding of the unborn for most types of exposure. Finally, the total period of potential exposure is small for the unborn compared to that for a worker—a period of months compared to a working lifetime.

It is difficult to provide for protection of the unborn without affecting the rights of women to equal job opportunities. This difficulty is compounded because the critical period for most harm to the unborn occurs soon after conception—during the second and third month after conception, when a woman may not know that she is pregnant. Based on our assessments of the risks and the other factors noted above, we believe that the maximum dose to the unborn should be a factor of ten below the maximum permitted adult workers in any year. This is also the current recommendation of the National

Council on Radiation Protection and Measurements. In Recommendation 8 we propose four alternatives which would, with varying degrees of certainty, achieve this objective.

The first two alternatives rely upon voluntary compliance and, therefore, should have less impact on equal job opportunities for women. The first assumes a woman knows she is pregnant within six weeks of conception, and will then, along with her employer, take appropriate protective action. It therefore does not guarantee that doses to the unborn during the critical early stages of pregnancy will be less than 0.5 rem.

The second alternative adds a voluntary limit on dose rate to women who can bear children in order to protect the unborn whose existence is not yet known. It permits women to hold any job, but encourages women able to bear children not to take those few jobs which potentially involve high dose rates.

The third alternative insures protection of all unborn throughout gestation by making the voluntary requirements of the second mandatory. It would bar women of child-bearing capacity from those few jobs which involve high dose rates.

The final alternative would restrict the exposure of all workers, male and female, to a level which would protect the unborn at the level of the first alternative. This alternative preserves equal job opportuntity for women at the cost of causing more total harm. Studies of several high exposure activities show that decreasing the dose limits to this extent would significantly increase the collective dose to workers, and that some current activities would not be possible.

None of these alternatives is completely satisfactory; they each involve either varying degrees of adequacy of protection of the unborn, some sacrifice of equal job opportunity for women, or causing more total harm, or foregoing some of the benefits to society from activities using radiation. We invite public comment on the relative importance to be attached to each of these factors in formulating guidance, and on whether or not the guidance should address this matter now. We would also be happy to receive suggestions for other alternatives.

Limitation of Other Risks

The risk of nonfatal cancer is not only intrinsically less important than that of fatal cancer, but is very much smaller than other nonfatal occupational risks. Thus, we believe the protection provided against fatal cancers includes adequate protection against nonfatal cancers.

While adequate protection against cataracts of the lens of the eye might be provided by a higher maximum average annual dose than the 5 rem now allowed, no operational difficulty is reported with use of 5 rem as an annual limit. That value is therefore retained in these proposals.

The maximum annual dose for skin of the whole body is maintained at 30 rem, since a need for allowing higher doses has not been demonstrated. However, the current guide permits 75 rem to hands and forearms, or feet and ankles, because of the assumed lower risk when only these portions of the skin and underlying tissue of these extremities are involved. We agree that at low dose rates the risk depends in some degree on the amount of skin and tissue exposed, and that exposure of the extremities is therefore less dangerous than of the whole body. However, for forearms, feet, and ankles such a high value is not needed and we propose that the guides for skin and the whole body apply to these extremites. For the hands a higher value appears to be justified for work in glove boxes. It is proposed to be 50 rem, the limit recommended by the ICRP.

Other Considerations

These recommendations apply to workers exposed to other than normal background radiation on the job. It is sometimes hard to identify such workers, because everyone is exposed to natural sources of radiation and many occupational exposures are small. Regulatory agencies will have to use care in selecting classes of workers whose exposure does not need to be regulated. In selecting such classes we recommend that the agency consider both the collective dose which is likely to be avoided through regulation and the maximum individual doses possible.

The question often arises whether or not exposure for medical purposes and other nonoccupational exposures should be considered in calculating the doses that workers receive within the guides. If there were a threshold for risk of health effects from radiation, this could be an important consideration. However, since we assume that the risk at low doses is proportional to the dose, each exposure must be justified on its individual merits. For this reason, in Note 1 to the recommendations we exclude medical and other nonoccupational exposure from the total calculated occupational radiation exposure of workers.

In many jobs diagnostic x-ray examinations are a routine part of periodic or pre-employment physical examinations. Some of these examinations are a condition of employment and some are not. Federal radiation protection guidance on use of diagnostic x-rays was issued by the President on February 1, 1978 (43 FR 4377). These recommendations provide that, in general, use of such x-ray examinations should be avoided unless a medical benefit will result to a worker, considering the importance of the x-ray examination in preventing and diagnosing diseases, the risk from radiation, and the cost. Although all of the recommendations in that guidance may be usefully applied to x-ray examinations of workers, Recommendations 1 through 4 are particularly pertinent. Because this matter has been addressed by separate Federal guidance, exposure from such diagnostic x-ray examinations is not included in this guidance for occupational exposure.

Current Federal guidance provides that occupational doses to minors (those below the age of eighteen) be limited to one tenth the RPGs for older workers. We propose no change.

No other general types of exposed workers are singled out for special protection by these recommendations. However, one special class of workers—underground uranium miners—is already subject to a separate Federal guide (36 FR 12921). That guide limits exposure of their lungs to radioactive decay products of radon gas. The Mine Safety and Health Administration regulates exposure of all underground miners in accordance with this guide. We expect to review the guide on the exposure of miners to decay products of radon in the future. Exposure of miners to other radiation is governed by the Federal radiation protection guidance in these proposed recommendations.

We have not addressed the issues of emergency exposures or of whether overdoses in one year should lead to additional restrictions on doses in future years. Such situations must be dealt with on the merits in each case and under the regulatory mandate of the controlling Federal agency. We do not consider it either practical or reasonable to prejudge or prescribe general conditions for such situations beyond the general principles which apply to all radiation exposure that are set forth below in Recommendations 1 and 2.

We recognize, in addition, that some situations may exist which justify planned exposures exceeding the guides. Recommendation 9 provides for this. It requires that the controlling Federal agency fully consider and disclose the reasons for any such exposures.

Estimated Impact of These Proposals

We estimated above that the exposure of 1.1 million workers in 1975 (the latest year for which we have complete statistics) will lead to 15–36 additional premature cancer deaths and comparable numbers of serious mutational effects and nonlethal cancers. If this new guidance is adopted, workers should be harmed less in the future. We are not able to quantify the improvement because we cannot predict how efficiently the guidance will be implemented and we do not know how much of existing exposure is unjustified. However, the proposed recommendations provide a framework of graded minimum requirements to cut down the amount of unjustified exposure, and a recommendation that implementing agencies establish lower regulatory limits for workers who can operate significantly below the new maximum limits. We believe that most workers can. The proposals also reduce the maximum annual and lifetime dose that any workers can get by about 60%.

We have made only a limited assessment of the costs of implementing this proposed guidance. We do not believe it would be prudent to attempt a detailed analysis, because agencies developing regulations to carry out this guidance may use different means, and their specific proposals will be subjected to public review and economic analysis when they are developed.

The principal cost will be that associated with reduced RPGs. in order to comply with a reduced RPG an enterprise can hire more workers, reassign (and, if necessary, retrain) present employees, improve its procedures or technology, or curtail the activity. In general, a mix of these will be used, depending on the value of the reduced RPG, on the cost of each alternative, and on other factors. Since we do not know what mix will be used, for the purpose of developing rough numberical estimates of the upper bounds of costs we have used a simple model based on the costs for hiring new workers only.

From the distribution of doses found in our national survey of exposures for the year 1975, we computed the total excess collective dose between the old RPG of 3 rem per quarter and the proposed RPG of 5 rem per year. Dividing this excess by the value of the proposed new RPG gives the minimum number of workers that must be hired to absorb this dose. The average labor cost, including overhead, for each additional worker was assumed to be $40,000 per year. This method yields a cost of about $35 million per year. We believe the actual cost of meeting the new RPG will be much less.

We have also attempted to evaluate costs if existing workers now receiving lower doses are retrained to do high-dose jobs instead of hiring new workers. Some workers are very difficult to replace (e.g., medical professionals, such as cardiologists and radiologists; and workers in small enterprises with very limited labor pools). However, we believe that most workers can be relatively easily retrained (e.g., medical technicians and skilled laborers, such as welders and pipe fitters) to handle tasks which cause higher exposures. We estimate that workers that can be reassigned to these jobs would require training varying from a few days to a few months. For these workers, the costs are expected to range from a few percent to a few tens of percent of the annual cost of new hires. In addition, these costs are incurred only once instead of annually, as in the case of new hires. We therefore estimate that the costs based on the above new hires model may be as much as ten times too high, for the first year, and an even greater over-estimate in succeeding years. We welcome comments on the costs of implementing these proposals, on whether or not the costs are reasonable, and why.

Proposed Recommendations

We propose nine recommendations as guidance to Federal agencies in the formulation of Federal radiation protection standards for workers, and in their establishment of programs of cooperation with States. In all cases but one we have made single recommendations for public comment. The exception, Recommendation 8, addresses protection of the unborn during gestation. Because this recommendation involves issues that go beyond simple radiation protection of workers, including equality of employment rights and the rights of the unborn, we have proposed four alternatives for public consideration. The recommendations follow:

1. All occupational exposure should be justified by the net benefit of the activity causing the exposure. The justification should include comparable consideration of alternatives not requiring radiation exposure.

2. For any justified activity a sustained effort should be made to assure that the collective dose is as low as is reasonably achievable.

3. The radiation dose to individuals should conform to the numerical Radiation Protection Guides (RPGs) specified below. Individual doses should be maintained as far below these RPGs as is reasonably achievable and consistent with Recommendation 2.

Radiation Protection Guides

a. The sum of the annual dose equivalent [6] from external exposure and the annual committed dose equivalent [7] from internal exposure should not exceed the following values:

Whole body—5 rem
Gonads—5 rem
Lens of eye—5 rem
Hands—50 rem
Any other organ—30 rem

b. Non-uniform exposure of the body should also satisfy the condition on the weighted sum of annual dose equivalents and committed dose equivalents,

H_w, that

$$H_w = \Sigma_i w_i H_i < 5\text{rm},$$

where w_i is a weighting factor, H_i is the annual dose equivalent and committed dose equivalent to organ $_i$, and the sum excludes the gonads, lens of eye, and hands. Recommended values of w_i are:

Breast—0.20
Lung—0.16
Red bone marrow—0.16
Thyroid—0.04
Bone surfaces—0.03
Skin—0.01
Other organs [8]—0.08

c. When both uniform whole-body exposure and nonuniform exposure of the body occur, in addition to the requirements of 3a, the annual uniform whole-body dose equivalent added to the sum of weighted annual dose equivalents from additional nonuniform exposure, H_w, should not exceed 5 rem.

4. The following Minimum Radiation Protection Requirements should be established by appropriate authorities and carried out in the workplace, on the basis of the range of doses anticipated in individual work situations. The numerical values specifying the dose ranges may be adjusted to fit the needs of specific situations by implementing agencies.[9]

---

[6] "Dose equivalent" means the quantity expressed by the unit "rem," as defined by the International Commission on Radiation Units (IU73).

[7] "Annual committed dose equivalent" applies only to dose equivalents from radionuclides inside the body. It means the sum of all dose equivalents that may accumulate over an individual's remaining lifetime (usually taken as 50 years) from radioactivity that is taken into the body in a given year.

[8] Applies only to each of the five other organs with highest doses.

[9] Suggested numerical ranges are: Range A, less than 0.1 RPG; Range B, 0.1–0.3 RPG; Range C, 0.3–1.0 RPG.

Minimum Radiation Protection Requirements

Range A

a. Determine that exposures result only from justified activities and are as low as is reasonably achievable. These determinations may often be made on a generic basis, that is, by considering groups of similar work situations and protective measures.

b. Monitor or otherwise determine individual or area exposure rates to the extent necessary to give reasonable assurance that doses are within the range and are as low as is reasonably achievable.

c. Instruct workers on basic hazards of radiation and radiation protection principles, and on the levels of risk from radiation and appropriate radiation protection practices for their specific work situations. The degree of instruction appropriate will depend on the potential exposure involved.

Range B

The above requirements, plus:

d. Provide professional radiation protection supervision in the work place sufficient to assure that both individual and collective exposures are justified and are as low as is reasonably achievable.

e. Provide individual monitoring and recordkeeping.

Range C

The above requirements, plus:

f. Justify the need for work situations which are expected to make a significant contribution to exposure in Range C and provide professional radiation protection supervision before and while such jobs are undertaken to assure that collective and individual exposures are as low as is reasonably achievable.

g. Carry out sufficient additional monitoring of workers to achieve Recommendation 4f.

h. Once a worker has been exposed in Range C, maintain a lifetime dose record, including at least all subsequent annual doses (as specified in Recommendation 3c) in Ranges B and C.

i. Maintain lifetime doses as low as is reasonably achievable. The accumulation of doses (as recorded under Recommendation 4h) by individual workers should be managed so that their lifetime accumulated dose is less than 100 rem.

5. a. "Radioactivity Intake Factors" (RIFs) should be used to regulate occupational radiation hazards from breathing, swallowing, or immersion in media containing radionuclides. The RIF for a radionuclide is defined as the maximum annual intake (in curies) for which the committed dose equivalent to a reference person satisfies the Radiation Protection Guides in Recommendation 3. RIFs may be derived for different chemical or physical forms, and for intake by breathing, swallowing, or for external exposure from air containing a radioactive gas. Exposure regulated through use of the RIFs should meet the same Minimum Radiation Protection Requirements as equivalent exposure under the Radiation Protection Guides.

b. When a RIF for a specific radionuclide in a specific chemical or physical form determined on the basis of part (a) is larger than that currently in use, a value no greater than that in current use should be adopted in regulations governing work situations identical or similar to those currently in existence.

6. Federal agencies should establish limits and administrative levels that are below the RPGs and the RIFs, when this is appropriate. Such limits or levels may apply to specific categories of workers or work situations.

7. In addition to any other Federal restrictions, the occupational exposure of individuals younger than eighteen should be limited to one tenth of the Radiation Protection Guides for adult workers.

8. Exposure of the unborn [10] should be restricted more than that of workers. This should include special consideration of ALARA practices for women. Women able to bear children should be fully informed of current knowledge of risks to the unborn from radiation. In addition, employers should assure that protection of the unborn is achieved without loss of job security or economic penalty to women workers. Due to the complexity of the issues involved, we propose four alternative recommendations on numerical limitation of dose to the unborn for public comment. We would be glad to receive other recommendations for dealing with exposure of the unborn.

a. Women are encouraged to voluntarily keep total dose to any unborn less than 0.5 rem during any known or suspected pregnancy; or

b. Women able to bear children are encouraged to voluntarily avoid job situations involving whole-body dose rates greater than 0.2 rem per month, and to keep total dose to the unborn less than 0.5 rem during any known pregnancy; or

c. Women able to bear children should be limited to job situations involving whole-body dose rates less than 0.2 rem per month. Total dose to the unborn during any known period of pregnancy should be limited to 0.5 rem; or

d. The whole-body dose to both male and female workers should not exceed 0.5 rem during any six month period.

9. In exceptional circumstances the RPGs may be exceeded, for cause, but only if the Federal agency having jurisdiction carefully considers the specific reasons for doing so, and publicly discloses them unless this would compromise national security.

The following notes clarify application of the above recommendations:

1. Occupational exposure of workers does not include that due to (a) normal background radiation and (b) exposure as a patient of practitioners of the healing arts.

2. When the uniform external whole-body exposure occurs in addition to exposure from radioactive materials taken into the body, the requirement of Recommendation 3c may be satisfied by the condition that

$$\frac{H_{ext}}{RPG_{wb}} + \sum_{j} \frac{I_j}{RIF_j} \leq 1,$$

where $\bar{H}_{ext}$ is the annual external whole-body dose equivalent, RPG_{wb} is 5 rem, I_j is the intake of radionuclide j, and RIF_j is defined as in Recommendation 5.

3. The values currently specified by the ICRP for quality factors and dosimetric conventions for measurement of the various types of radiation may be used for determining conformance with the RPGs. The model for a reference person and the metabolic models currently specified by the ICRP may be used to calculate the RIFs. We will recommend other factors, conventions, and models when and if they are more appropriate.

4. Numerical guides for emergency exposures are not provided by this guidance. Agencies should follow the general principles established by Recommendations 1, 2, 7, 8, and 9 in dealing with such situations.

5. Procedures for handling overexposures are not addressed by this guidance. The equitable handling of such cases is the responsibility of the employer and the Federal agency having regulatory jurisdiction.

6. Limits for periods other than one year may be derived by Federal agencies from the annual RPGs and RIFs when necessary for administrative

---

[10] "Unborn" here means the fertilized oocyte, the embryo, and the fetus.

purposes. Such limits should be consistent with Recommendation 2 and the three ranges in Recommendation 4.

7. The existing guide for limiting exposure of underground uranium miners to radon decay products is not changed by these recommendations.

These proposed recommendations would provide general guidance for the radiation protection of workers. They would replace that part of existing guidance (see 25 FR 4402 of May 18, 1960) which applies to workers. Individual Federal agencies, with their knowledge of specific worker exposure situations, would use this guidance as the basis upon which to develop detailed standards and regulations to meet their particular statutory obligations. We propose to follow the activities of the Federal agencies as they implement the final Guidance, to issue any necessary clarifications and interpretations, and to promote the coordination necessary for an effective Federal program of worker protection.

Public Hearings

Public hearings on these proposed recommendations will be held as indicated above under the heading "Dates." Because of their major responsibilities to regulate radiation exposures in work places, the Nuclear Regulatory Commission (NRC) and the Occupational Safety and Health Administration (OSHA) will participate in sponsoring these hearings. The following conditions and procedures will govern the conduct of the hearings:

1. Purpose, Type, and Scope

These hearings are to provide additional opportunity for people to express opinions and provide factual information to aid EPA, OSHA, and NRC in carrying out their respective responsibilities for guidance on and regulation of occupational exposure to ionizing radiation. The hearings will be informal and legislative in nature rather than adjudicatory or formal rulemaking hearings. Technical rules of evidence, discovery, subpoena powers, testimony under oath, and similar formalities will not apply.

The issues to be covered by these hearings are those listed above under the heading "*Issues Addressed.*" They include those listed in our advance notice of September 17, 1979 (44 FR 53785) and additional issues suggested since then. As indicated in that notice, both EPA and NRC have been petitioned by the Natural Resources Defense Council, Inc., to revise occupational guidance and standards. The subject matter of these hearings encompasses the issues raised in those petitions (See 40 FR 50327 of October 29, 1975).

2. Presiding Officer and Panel

The hearings will be conducted by a presiding officer. A six member panel consisting of representatives of EPA, OSHA, and NRC will assist the presiding officer. A principal responsibility of the panel will be to clarify the testimony by eliciting views, comments, and factual information from participants. Members of the panel will not present views or respond to questions on behalf of their agencies. The membership of the panel may vary from time to time.

The presiding officer and panel shall have the joint responsibility to assure a fair and impartial hearing and to encourage the development of testimony that will contribute to informed decision-making. It will not be the function of the presiding officer or the panel to issue an opinion or to make decisions at the conclusion of the hearings. The presiding officer shall conduct the hearings in an orderly, fair, and expeditious manner and make procedural decisions. His functions shall include, but not be limited to, the following:

a. Regulating the course of the hearings and the conduct of participants, including establishing reasonable time limits for the hearings, establishing the sequence and length of presentations and questioning, and opening and closing each hearing session;

b. Making determinations concerning procedure and similar matters;

c. Assuring that questioning of speakers by panel members and others is consistent with the nature and purpose of these hearings;

d. Making determinations on the relevance of oral testimony and questions to the issues identified as within the scope of the hearings, or, in consulation with the panel, to additional issues pertinent to the proceedings; and, as necessary, terminating irrelevant presentations;

e. Ruling on late requests to participate;

f. Deciding how long the hearing record will remain open for written comments and additional data after the end of the oral proceedings.

3. Participation in the Hearings

Persons or organizations who wish to give presentations longer than ten minutes or present extensive data and evidence must give written notice to the Director, Criteria and Standards Division (ANR-460), U.S. Environmental Protection Agency, Washington, D.C. 20460, no later than 28 days prior to the scheduled date of a hearing. The notice should include: (1) the name, address, and telephone number of the participant; (2) the hearing at which they wish to testify; (3) the organization (if any) that they will represent; (4) the amount of time requested; and (5) which of the issues they want to address. Oral presentations will generally be restricted to 30 minutes. Detailed or lengthy material should be summarized orally and presented in full in written submissions. Requests for longer times for oral presentations will be condsidered only on the basis of a detailed summary of the material to be presented. The Agency will notify participants in advance if their allocated time is less than that requested.

An opportunity will be provided each day of the hearings for persons who have not submitted a notice as specified above to make brief oral statements. A register will be provided at the beginning of each hearing for this purpose. A minimum period will be set aside for such statements in the agenda for each hearing, and the presiding officer may allocate additional time, as necessary. The maximum time allowed for such statements will depend on the number of registrants and the availability of time, but will generally be limited to periods of no more than 5 to 10 minutes each. In order to assist the management of the hearings, persons wishing to make such statements are encouraged to register promptly at the beginning of the hearing.

Attendance at the hearings will be open to all members of the public, and seating will be made available on a first-come first-served basis.

4. Testimony and Written Submission

a. The oral proceedings will be recorded verbatim and a transcript made availabe promply for inspection and copying, as specified below under the heading "The Public Hearing Record." It will help the panel if speakers supply copies of their oral testimony before they give it. However, this in not required.

b. Fourteen copies of any written statements and documents on which speakers intend to base their oral statements must be submitted to the Director (see "Addresses" above) no later than 14 days before the beginning of the hearing in which they will testify. We would appreciate if speakers would also provide eight additional copies for the use of the panel.

c. Questions may be directed to speakers by the hearing panel, by other speakers, and by other members of the public. Speakers may respond or not, as they wish. Questions should be designed to elicit relevant information and should not be repetitious of questions asked by others. The views of questioners should be expressed in their statements and not as prefaces to questions. Such informal questioning will be at the discretion and under the control of the presiding officer.

d. Members of the public who are not able to attend the hearings or prefer not to ask questions themselves may suggest questions to the hearing panel to ask of speakers. These must be submitted no later than 14 days before any hearing to the Director (see "Addresses" above). The panel will decide whether or not to ask these questions.

e. Members of the public may also submit comments during the post-hearing comment period set by the presiding officer. These post-hearing comments should be confined to responses to data and opinions submitted at the hearings or to written comments received by the Agency.

f. In addition to these public hearings, we would appreciate any written comments on these proposals. These will be given equal consideration in formulating final recommendations. The procedure for submitting such written comment is given above under the headings "Dates" and "Addresses." Participants in the hearings may refer to and comment on such written comments, which will be available for public inspection and copying as specified below under "The Public Hearing Record."

5. Opening Statement

At the opening of each hearing, EPA will provide a summary statement of the proposed recommendations and of the major issues involved. At that time speakers and other members of the public can ask questions of the EPA representatives in order to clarify the proposed recommendations and the reasons why EPA is proposing them.

6. The Public Hearing Record

The procedures for filing documents in these hearings will be specified by the presiding officer, except as already provided herein.

The hearing record will include the transcript of oral statements by speakers, the questions and answers, and all written materials filed in connection with these hearings. Items in this public hearing record will be filed under EPA Docket No. A-79-46 and will be available for public inspection and copying as soon as possible following their receipt, at the U.S. Environmental Protection Agency's Central Docket Section, Room 2903B, Mall, 401 M Street, S.W., Washington, D.C. 20460, and at each of the Agency's ten regional offices (see "Addresses" above).

Dated: January 16, 1981.

Douglas M. Costle,

Administrator.

[FR Doc. 81-2366 Filed 1-22-81; 8:45 am]

BILLING CODE 6560-26-M